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DISEASES OF FOREST-TREE NURSERY STOCK

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and

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UNITED STATES DEPARTMENT OF AGRICULTURE

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NOTE.—Published and unpublished observations and data of the following persons were freely used: Dennis H. Latham, Assistant Forest Pathologist; George Y. Young, Assistant Pathologist; Howard Lamb, Assistant Pathologist; Bailey Sleeth, Assistant Pathologist; and E. Haven Tryon, Junior Pathologist, all formerly CCC, Division of Forest Pathology. In addition, the cooperation of Federal nurserymen of the Prairie States Forestry Project, Forest Service, and Soil Conservation Service, United States Department of Agriculture; National Park Service, and the Civilian Conservation Corps, United States Department of the Interior; Tennessee Valley Authority; and of State nurserymen has made possible the accumulation of much of the information contained herein. This publication should prove useful to CCC technicians, foremen, crew leaders, and nursery workers, as well as to Federal, State, and private forestry agencies having forest nurseries.

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Enrollees seeding pine in a nursery.

DISEASES OF FOREST-TREE NURSERY STOCK

INTRODUCTION

With the establishment of the Civilian Conservation Corps there was a decided increase in artificial reforestation in this country. Since the start of the Corps in April 1933, enrollees have put in 5,625,964 man-days on forest-nursery work. This has included clearing and leveling of land, preparation of seedbeds, installation of watering systems, and planting and care of tree seedlings, as well as transplanting, pulling, bundling, and shipping of seedlings. A total of 22 forest-tree nurseries has been constructed, largely with CCC labor. At many of these nurseries and at about 100 additional ones CCC labor has been used for operation purposes. In addition to the Corps' contribution to the production of forest-tree seedlings, CCC enrollees have planted the stupendous total of 2,246,100,000 young trees on potential forest lands and on soil-conservation and flood-control projects. The interest of the Corps, therefore, in all phases of reforestation has been very practical and its contribution to the cause most important.

"Diseases of Forest-Tree Broadleaf Nursery Stock" was issued in mimeograph form in 1941 as No. 9 in the Forestry Publications series of the CCC. It has been revised and combined with "Diseases of Conifers in Forest Nurseries," the mimeographed circular issued by the Division of Forest Pathology, Bureau of Plant Industry, and is herewith issued in printed form as No. 9 in the Foresty Publications series. This publication presents information regarding the causes of the more frequently encountered nursery diseases and the chemical treatments and general nursery practices that will reduce losses associated with them. Since forest planting stock is seldom held in the nursery for more than 4 years, disease affecting only trees older than that will not be considered. Proper shading, watering, fertilizing, and soil amending are probably as important in avoiding or controlling diseases as are the specific disease-preventive treatments. The major part of the adaptation of local nursery practices to disease prevention will have to come through the observations and tests made by the nursery production staff, or perhaps better by local technical service men or experimenters. The disease-control program cannot be developed independently of other nursery practices; at each nursery it must be fitted to and made a part of the local scheme of operations. The nurserymen must guard against diseases that interfere with mass production of planting stock and those that may cause only slight losses in the nursery but may do serious damage if introduced into plantations.

People who are interested in the problems discussed in this publication, but who are not experienced in handling poisonous chemicals, should be careful to secure skilled advice and supervision before using treatments hereinafter outlined. The degree of protection needed depends on the kind of chemical that is used. For poisonous and irritating dusts, such as copper compounds, Ceresan, etc., and sprays containing the same or similar compounds, the use of a full face-piece respirator equipped with a filter element is advised.

Identification and specific control suggestions for new diseases or those of infrequent occurrence may be obtained by writing to the Division of Forest Pathology, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C. Specimen material preferably should accompany such inquiries.

DIAGNOSTIC AIDS AND SUGGESTIONS FOR MAILING DISEASED SPECIMENS

A large proportion of the cases of injury to seedlings are of types that cannot be diagnosed merely from specimens, and are sometimes difficult to diagnose even when a pathologist is present to watch the trouble as it develops. Diagnosis is much more certain at nurseries where all beds have not been treated alike. Where by accident or design some beds have different watering, shading, fertilization, rotation, or disinfectant treatments, it is often possible to determine immediately the cause of loss and quite often the remedy also by simply comparing the results in beds that have been treated differently. When any specific treatment is being used, such as fungicide, commercial fertilizer, or green manure, it is urgently advised that a few scattered small beds or plots be left untreated or with stronger or lighter treatments than the general areas. With species or classes of stock on which shading or watering is not being done generally, it would help the diagnosis of any obscure losses that may develop later if a few small plots are watered differently or shaded.

When it is necessary to send specimens away for diagnosis, apparently healthy trees as well as sick ones, showing the earliest symptoms and the more typical diseased condition, should be included. Unless the trouble is definitely limited to parts above ground, as large a part of the root system as it is practicable to mail should be included. The root system should be carefully dug or washed out to avoid loss of absorbing roots. Particularly where heat injury is suspected, each seedling should be marked at the soil surface on the north side before digging. Plants that are diseased but not dying are best sent with their roots still in the original soil. Living material may be sent in moist sphagnum moss. Leaves and other dead parts of plants are best sent dry, or in commercial formaldehyde solution diluted with six parts of water. The formaldehyde solution should also be used in shipping roots to be examined for mycorrhizae. Data on the locality, appearance of the trouble in the field, extent of damage to different species, and any observations that have been made on relation of the trouble to chemical treatment, nursery practice, or differences in environment should be enclosed in the specimen package.

DISEASE PREVENTIVE MEASURES

Those concerned with nursery-stock production have, and sometimes to their sorrow, found the statement by Dickens in "Martin Chuzzlewitt," "prevention is better than cure," to be a truism. With little effort certain general preventive measures can be applied as part of the nursery operations. A discussion of the more important of these follows.

SELECTION AND PREPARATION OF NURSERY SITES

Perhaps one of the simplest precautions that can be taken is the careful selection of forest-tree nursery sites. Nematodes have usually been most troublesome on sandy soils, although such soils generally are a safeguard against damping-off and root rot. Very porous sandy soils, however, sometimes predispose the seedlings to drought and deficiency diseases. Sites having a good air drainage are less apt to be associated with top wilts. For conifers a site with acid soil (with a low pH value) should be chosen. The most desirable acidity for most of the conifers that are subject to damping-off is probably in the neighborhood of pH 5.0, while for eastern redcedar, as for most broadleaf species, 5.5 to 7.0 is believed to be a desirable pH range. Alkaline soil, especially when it contains enough carbonate to effervesce visibly when treated with acid, favors damping-off, root rot, and chlorosis of the more commonly produced forest conifers to such an extent that it is inadvisable to grow these species on neutral or alkaline soils if it is possible to use acid locations. A soil pH value as low as 4.5 does no obvious harm to most conifers; on especially light sands, low pH values sometimes are associated with insufficient minerals necessary for vigorous growth. Soils with a high nitrogen or very low phosphorus content are to be regarded with suspicion, as predisposing to disease. As the soil texture, fertility, etc., are apt to vary within any given nursery, allocation of species to the units best suited for each should be made.

Before permanently adopting a proposed site where soil acidity, texture, or drainage is not ideal, it is wise to make test plantings on it for one or more seasons. There is not yet enough known of the factors affecting diseases to enable anyone to predict postively the amount of disease to be expected on a particular site.

In the nursery, it is safest to avoid sites near older stands of the same species to be grown, since older trees frequently harbor fungi or insect parasites that may attack young seedlings. Where this is not possible, the nursery species similar to those in adjacent stands should be isolated to the more remote parts of the nursery; or, if the stands of such trees around the nursery are small, they may be eliminated by cutting. The diseases to be particularly looked for in the vicinity of a possible conifer nursery site are given in table 1.

Areas previously used for gardens, livestock yards, and human habitations have often proved unsatisfactory as nursery sites. Within such areas soil nitrogen, acidity, and physical properties may vary so much as to increase the disease hazard and make it difficult to organize corrective treatments.

Sites chosen should be level enough to require little grading; exposure of subsoil in grading operations results in variation in soil conditions which makes it difficult to adjust soil treatments. In preparation of the site, old stumps, and large roots should be grubbed out to avoid mass infection with root-rot organisms.

Since clay soils increase likelihood of root rot and of heaving in winter, where the water table is relatively high, a somewhat sandy and well-drained soil is desirable. However, very sandy soils or ones with very low water tables may also be undesirable. On sand with a wilting coefficient of less than 4 percent, coniferous stands of normal

density may be subject to drought and chemical-deficiency diseases. Soil that is too sandy also increases the likelihood of heat injury to stems at the soil surface.

TABLE 1.—*Disease-preventing practices for conifers*

Types and species and their diseases	Areas	Treatments and practices to be applied to zone around nursery
5-Needled Pines:		
White pine blister rust (*Cronartium ribicola*).	Wherever the rust is established.	Remove all ribes to minimum distance of 1,500 feet; dangerous species (*R. nigrum*, and in the West also *R. petiolare*, *R. bracteosum*, and others) and heavy concentrations of any ribes species, should be cleaned out within a radius of at least 1 mile. It is also a good practice to remove any infected pine in the neighborhood. Before undertaking the work, the State nursery inspector, or the State or Federal blister-control organization should be consulted.
Hard Pines in General:		
Short-cycle gall rusts (*Peridermium harknessii*, Woodgate rust).	West, New York.	Cut out infected trees.
Alternate-host gall rusts (*Cronartium cerebrum*, *C. fusiforme*).	East and South	It is theoretically advisable to cut out infected pine, and any species of the black-oak group of which the leaves show infection. Preliminary tests show that the cleared zone may have to be more than one-half mile in width; this may be impracticable.
Blister rusts (stem rusts without gall formation, *Cronartium filamentosum*, *C. pyriforme*).	West	Cut out infected trees. If any rust can be found on lower surface of leaves of Indian paint-brush (*Castilleja* spp.) or bastard toadflax (*Comandra pallida*), eradicate them. Submit doubtful specimens to a pathologist.
Blister rusts (*C. comptoniae*, *C. pyriforme*).	East	Cut out infected trees. Eradicate *Comptonia*, *Myrica*, or *Comandra* if found with rust.
Needle rusts (*Coleosporium* spp.).	All	If these rusts are causing real damage in the nursery, mow or otherwise eliminate composites and morning glories about July; repeat if the composites make much late-season growth.
Needle casts (*Lophodermium*, *Hypoderma* spp.).	do	If needle casts are doing real damage in nursery, cut out all infected pines within 100 yards, and trees that repeatedly show heavy infection within 300 yards.
Dwarf mistletoe (*Arceuthobium* spp.).	West	Prune or cut out infected hard pines.
Austrian, Maritime, Longleaf, and other Hard Pines:		
Red- and brown-spot needle blights.	Central, South, and Southeast.	Spray (4-4-50 Bordeaux) or remove any infected trees within 100 yards.
Spruce:		
Needle rust (*Chrysomyxa* spp.).	North and North Central.	If rust is causing real damage in nursery, remove leather-leaf and Labrador tea.
Douglas-Fir:		
Needle blight (*Rhabdocline*).	West	Eradicate Douglas-fir showing infection.
Dwarf mistletoe	do	Cut out or prune infected Douglas-fir.
Spruce and Balsam Fir:		
Snow blight (*Phacidium*)	Northeast	Remove infected branches 200 yards around nursery.
Western Larch; Dwarf mistletoe.	West	Cut out or prune infected larch.
Red and Coast-White Cedars:		
Gall and stem rusts	East	Cut out apple relatives (*Crataegus* and *Amelanchier* for white cedar) if found with cluster-cup rust stage on fruit or lower surfaces of leaves.
Cedar blight (*Phomopsis*).	All	If much redcedar is being produced, where practicable eradicate all infected redcedar within 500 feet or more.

A site that slopes strongly to the south or southwest predisposes to heat injury. In northern regions with dry winters there is also need to avoid too much exposure to northwest winds, unless mulch is to be used. Sites with poor air circulation are to be avoided, for during humid or rainy seasons this condition is a predisposing factor to top damping-off or other foliage and stem infections.

On sites of much lower elevation than the seed source, the losses from damping-off and other diseases are likely to be greater than on a site somewhat nearer the natural altitude—a theoretical supposition

supported by several years' experience with Douglas-fir from different elevations in the Northwest.

If the new site is to be on an area under cultivation, examination of the crop plants being grown may indicate the presence or absence of insect pests or parasitic fungi. As past experience has shown that some gases emanating from industrial plants may cause severe burning of seedling foliage, it is advisable to locate the nursery several miles from such factories.

DRAINAGE AND SAFE WATER SUPPLIES

Tile or open-ditch drainage of wet nursery sites should decrease the likelihood of root rot. The practice of raising the level of the beds above the paths is probably advisable on poorly drained sites. This should decrease the liability to root rot and in some cases to top-killing. Arched surfaces do not seem to be advantageous.

Certain water supplies may increase the disease hazard. Some water supplies are alkaline and with their continued use the pH of certain soils is gradually raised, resulting in increased damping-off, root rot, and sometimes chlorosis or other detrimental effect on seedling growth. The raising of pH varies with the amount of alkaline material in the water, the amount of water used, the evaporation rate, and the buffering capacity of the soil. High pH is more detrimental to pine, spruce, and fir than to cedar and broadleaf species. Where soils are sandy or originally had a low pH value and the water shows a total hardness as $CaCO_3$ of 100 parts per million or as bicarbonate of 125 ppm., or over, the effect of the water on the pH of the local soil should be tested. It is often easier and of more practical value to make direct tests of the effect of the water on the soil than to get water analyses made. If the water has an important effect on the pH of the nursery soil, it will show first in the top one-fourth or one-half inch, and comparison of surface soil pH in beds that have been watered plentifully through the summer with surface soil at comparative points that have not received the water will show whether or not the alkaline effect of the water is of importance.

A high silt or colloidal content of the water supply is detrimental to good growth of nursery stock, since accumulated silt may partially seal over the soil surface, thus preventing the usual air movements between the soil and atmosphere and predisposing the stock to root disease.

A possible factor concerning which little is known is the presence of pathogens in the water. One nursery which had been relatively free from disease suffered losses when it started to irrigate with brook water. Inspection showed the presence of *Rhizoctonia* in the sand along the edges of this brook. Other damping-off fungi could easily be carried by water. It is likely that well water would generally prove to be more free from pathogens than that from lakes or streams, but there is at present no reason for avoiding surface water simply on this account.

SANITATION

The need for sanitary precautions in areas immediately adjacent to the nursery can often be determined by the extent of infection in

the nursery. Native diseases usually do not warrant as strenuous precautions as the introduced diseases, but should, nevertheless, be guarded against at many of the nurseries where they are not now interfering with the production of planting stock. Where conditions prevail that warrant action, as in the case of certain leaf diseases and insect pests, the affected plants if not valuable should be eradicated and if of special value should be sprayed with proper materials.

The diseases to be particularly looked for and action that may be taken outside the nursery to protect the coniferous nursery stock are summarized in table 1. As indicated in the table, some of the conifer needle diseases are worth attention only if they are so prevalent in the nursery as to affect the growth of late-summer food storage of the stock. However, most of the diseases listed need attention around the nurseries principally to avoid introducing infection into the plantations made with the nursery stock. Most of the diseases listed in the table are native and already generally established over the regions in which they are able to maintain themselves, but they may easily be absent from new planting sites, so that the use of clean planting stock may considerably delay and decrease the infection of the plantation. For instance, the brown spot of long-leaf-pine seedlings probably must kill more than 10 percent of the needle surface in the nursery to have any evident effect on development in the nursery; but if the seedlings are to be planted on a clean site in a part of the country where conditions favor brown-spot development, 1 percent needle infection on the planting stock might supply sufficient inoculum to result in damage to the plantation earlier than if the stock had been clean to start with. With the stem rusts and mistletoes, entirely clean stock is desirable as health insurance for the plantation it enters. Mistletoe in the neighborhood of the nursery should be cleaned out even if none is found on the stock. The distance to extend the protective zones must depend for each nursery on the amount of the local damage or hazard and on the ease of extending the zone. At many nurseries by utilizing infected trees for firewood the original zone can be kept clear and gradually widened at moderate expense. Where an alternate host like *Comandra* or leather-leaf is very abundant, it may be impracticable to attempt any eradication.

In the nursery itself, particularly in the case of leaf, stem, or twig diseases, sanitation calls for removing and burning or deeply plowing under the infected parts prior to new spring seeding of the same species. When the seriousness of a disease is in doubt on valuable stock, it would be advisable to isolate the infected or partly infected species to some remote section of the nursery until definite information regarding the disease hazard is obtained. In case the infected stock is of little value, the safe procedure would be to burn it. The possibility of introducing vicious seed-borne or trash-borne parasites may be materially reduced by inspection and thorough cleaning of the seed prior to sowing. Against ordinary damping-off the removal of dead trees probably has little value. The liability to injury by the shoestring root rot and possibly other root rots on new nursery sites can be decreased by removal of old tree roots when preparing the site.

Another sanitation practice well worth following is to avoid mulching the seedbed of a given species with leaves or refuse parts of plants

of the same or closely related species. Inspection of stock for disease in the nursery during the growing season and at time of lifting may be regarded as a sanitation precaution which will assist in avoiding the introduction of certain nursery diseases into field plantings. Infected seedlings could be culled out. Once established in plantations, such diseases may become serious and infected stock may lead to a rapid spread under favorable conditions. The cephalosporium and verticillium vascular wilts, which will be mentioned in more detail under "Elm," are examples of diseases that might cause trouble in this way. Root rots may also be spread in this manner.

Marking the drill rows by sowing some fast-germinating truck-crop seed along with the tree seed to facilitate early weeding is not to be recommended. Many truck crops are subject to the diseases that affect forest-tree seedlings and may, therefore, increase losses in the latter by building up undesirable soil parasites. If marking the rows is desirable, it would be advisable to use a less susceptible species, such as wheat, for the purpose. Transfer of stock from nursery to nursery constitutes an ideal method of spreading parasites and particularly hastening the distribution of any fungi that may have entered the country from abroad but that have not yet become widely established. Recent troubles at certain nurseries have apparently been due to fungi coming in from other localities. Where rooted stock must be so moved, the danger of carrying root infections may be somewhat reduced by washing the soil from the roots prior to transfer. The long-distance shipment of planting stock is generally not advisable since it likewise involves the danger of introducing parasites that are not found locally.

Nurserymen have been known to bring in soil in order to inoculate production areas with mycorrhizal fungi or other supposedly beneficial organisms. This practice is considered dangerous when the soil comes from old nurseries or distant localities, since it may introduce troublesome parasites. Soil brought in for this purpose should be from the nearest natural stand of the same species or genus; it should be brought in from a nursery only when soil from natural stands or field plantings is not available and then only from a nursery that is nearby and appears to be healthy.

Normal root nodules occurring on most leguminous species grown in nurseries are generally beneficial. As in the case of introducing soil for mycorrhizal fungi, the use of field soil for inoculation purposes is advised against. Where inoculation is necessary, artificially prepared cultures should be used to obviate the possibility of spreading disease.

Among the many other means of disease entrance into a nursery that should be guarded against are surface water supplies, seed, and movement between nurseries of road grading, cultivating, and harvesting machinery. Soil should be washed from machinery that is moved.

SEED SOURCE

The disease hazard is undoubtedly greater for some seed lots than for others. From theory and practical experience, so far as the latter is available, the greatest trouble in the nurseries is to be expected with seed strains that originated in places with soil or climate quite

different from that at the nursery. This has been especially pronounced in the case of damping-off of Douglas-fir. Data showing similar differences in damping-off losses have been obtained for ponderosa pine, the greatest loss generally being in stock from a distant seed source. Nurserymen producing chokecherry stock should choose the seed of this species with special care in relation to its source. There is considerable circumstantial evidence that a disease apparently caused by a virus and known to occur in Colorado and eastern Utah is carried by seed. Seed collections within the area where the disease is known to exist should be made only from plants having normal, dark green leaves. Some of the leaves of the diseased plants prematurely turn a brilliant red on one side in the early fall. Seed source is usually determined on the basis of adaptation to the field planting site, and cannot be varied to suit the nursery. However, because of its importance the seed source should be made a part of the record of epidemics or of tests of disease-control treatments.

SEED TREATMENTS

Dusting seed with red lead, sometimes used to increase visibility for sowing or to repel birds, apparently has no value against fungus diseases. Fungicidal dips and dusts applied to seed have shown value in protecting seed and seedlings of annual crops in some cases, but tests thus far on forest-tree species have not been conclusive. Such treatments are most likely to be successful where pre-emergence damping-off is an important factor; they are of little or no value in the prevention of post-emergence damping-off losses. Copper compounds used as seed dusts on sandy acid soils have been known to cause considerable injury to some broadleaf and conifer species. Nevertheless fungicidal seed dusts warrant further trial in places where treatment of the seedbed is not practicable and particularly when the losses are primarily of the pre-emergence type of damping-off. At present it appears to be inadvisable to adopt any regular practice of treating coniferous seed with hormone dusts prior to sowing to increase the number of seedlings emerging from a unit quantity of seed or as a damping-off control measure. Seed treatments of some potential indirect value in decreasing disease are those that hasten germination of slowly or irregularly germinating species. These probably enable a larger proportion of the seedlings to reach the age of resistance before the strictly infantile diseases develop. The resistance of the seed or of seedlings from the treated seed is likely to be lowered by drastic mechanical, chemical, or heat treatments of the seed, but speedier germination obtained by proper after-ripening treatments (i. e. stratification) might well be accompanied by improved vigor of the seedlings. Pure sand and acid peat moss usually are safe stratifying media. The chances of severe losses caused by fungi to seed which is being stratified can be reduced by placing the seeds of the larger seeded species so that they do not touch one another and by spreading the smaller seeds in thin layers. Greenhouse experimental data indicated no difference in the susceptibility to chemical injury of stratified and unstratified *Pinus strobus* seed by aluminum sulfate and formaldehyde treatments when applied at the more common rates. However, sulfuric-acid treatments at the more common rates of application appeared to reduce slightly the

emergence of stratified seed of *Pinus strobus*, while emergence of the unstratified seed was little altered. Until more evidence is available sulfuric-acid seedbed treatments against damping-off should be slightly lighter on stratified than on unstratified coniferous seed.

Dusting of seed prior to storage with products which evolve toxic gases or which may in some other way reduce the viability of the seed is to be avoided, particularly in instances where the seed is stored in closed containers. Serious emergence reductions have been observed to result from such a practice. However, certain dusts, such as the oxides of copper and zinc, are not injurious when used at minimum rates on some species and should reduce fungus development during storage. Further reference in this publication is made to treatments of seed of broadleaf species under "Diseases of Specific Hosts."

TIME OF SOWING

For conifers, early-spring sowing is usually better from the damping-off standpoint than late-spring or summer sowing, but this does not hold for all nurseries or for all seasons. At most nurseries in localities with cold winters the damping-off hazard can be decidedly decreased and in some places practically eliminated by fall sowing. At some other nurseries where winters are mild, the situation appears to be reversed—fall sowing invites rather than prevents damping-off. At nurseries with heavy and long-continued snow cover the value of fall sowing is much in doubt. Cold wet soil often favors seed decay by nondamping-off fungi. Fall seeding of chestnuts, walnuts, and many oaks eliminates cost of seed storage and the hazard of seed molding and decay in storage, but unless the planted seed is properly protected, involves the possibility of losses caused by rodents. The only way to be entirely certain as to the relation of time of sowing to disease hazard at any particular nursery is to try different times of sowing with seed from the same lot and at the same sowing density, and to repeat such comparisons in different years. Late-spring or summer sowing predisposes to heat injury and susceptibility to early fall freezes.

RATE OF SEEDING

In addition to causing the seedlings to be too tall, slender, and weak, stands that are too dense are subject to a distinctly greater disease hazard than are normal to thin stands of most species. In general, the greater the stand density the larger the number and percentage of seedlings that damp off. To compensate for damping-off losses over-dense sowings are, therefore, only partly successful, resulting in more uneven stands, even when the average production is satisfactory. In especially moist places or seasons, fungi may spread directly from seedling to seedling through the tops if the stand is so dense that each seedling is in contact with three, four, or more others. Killing of the seedlings in patches from this cause may occur even after the stock is too old to suffer from attack by ordinary damping-off. Over-dense sowing also brings about a greater danger from drought injury when the trees begin to compete with one another, and in 2–0 stock often results in chlorosis of spruce, Douglas-fir, and other conifers when the nitrogen supply is not plentiful. On the other hand, stands that are too open increase any liability to heat injury during the first

few weeks and to winterkilling later; a reasonably dense stand enables the seedlings to shade one another and has an effect similar to that of mulch during the winter. The proper density for each nursery and each species can be determined only by local experience and varies, of course, with the period that the seedlings are to be left in the beds. Considerable decrease in many nursery diseases in recent years has been due to the practice of thinner sowing than that in use 30 years ago. In general, from the pathological standpoint there are still more errors in the direction of too dense sowing than of too thin sowing. Cases have been observed in moist climate where the spread of killing fungi from top to top in 2–0 pine beds and 1–0 black locust could only be effectively checked by systematic thinning or vigorous pruning.

SOWING AND COVERING SEED

Sowing too deeply definitely increases the disease hazard from damping-off fungi. Faulty drill mechanism, resulting in failure to drop the seed, explains some of the gaps in drills. On soils that tend to cake, seed sown in drills are better able to "crack" the soil and emerge before they are smothered into fungus susceptibility. However, drill sowing gives a better chance for fungi to spread from seed to seed or seedling to seedling and, in general, results in a somewhat larger percentage of damped-off seedlings than does broadcast sowing, provided the total number of seeds sown per bed is the same by each method. Furthermore, damping-off losses in drill-sown longleaf pine and 2–0 spruce have been observed at several nurseries and over several seasons to be more severe than in broadcast-sown beds. While broadcast sowing is generally preferable from the disease-control standpoint, its superiority is not enough to require its use in nurseries where drill sowing is preferred for other reasons.

For cover soil, while it is desirable from the damping-off standpoint to have one which will not cake and delay the emergence of seedlings, the use of pure sand does not have as much value in avoiding damping-off as has been attributed to it. The use of pure sand may also increase the liability to heat injury to stems at the soil surface. One place where a pure sand or gravel cover may have direct value against seedling diseases is in nurseries where prolonged snow cover causes molding of such species as Douglas-fir by pressing them into the surface of the bed.

Many broadleaf species do well if sown at a depth several times the short diameter of the seed; however, for either small seeded genera, such as *Betula*, *Lonicera*, and *Morus*, or large seeded genera such as *Juglans* and *Carya*, empirically determined depths should be used. Too shallow sowing may result in insufficient moisture for germination, seed being blown away, and an open way for increased seed loss from birds.

At some of the nurseries where heavy soils prevail, or where all of the available sand is too alkaline, it has been found advantageous to sow most species on the surface of the soil and cover the seed with organic matter, such as ground peat, sawdust, stave tow, pine needles, or a combination of sand and organic matter. For spruce and longleaf pine, however, results with the needle seed cover have been unfavorable. Sawdust seed cover has been used with decided success, appearing to be one of the best available methods of preventing long-

leaf pine damping-off losses. Where sawdust is used, old and preferably hardwood supplies should be employed, as "fresh" sawdust may exert a toxic effect on the germinating seeds and seedlings. If possible, organic matter should not be used as a seed cover at places where heat injury is known to occur, as this material absorbs more heat than the mineral soil. Sand containing highly reflective particles about the size of a pea should be avoided also as its use has resulted in increased heat injury to the stems of seedlings.

An alkaline cover soil should not be used. Its use results in a definite increase in damping-off and chlorosis, especially for conifers. A seed cover of a ¼-inch layer of sand containing 5 percent of limestone or shell fragments is equivalent to a treatment of approximately 2 tons of lime per acre. There is a positive correlation between seedling survival and the number of times alkaline sand has been used in covering the seed; areas that have been sanded once have a higher survival count than those which have been seeded and covered with alkaline sand twice. Continued use of alkaline sand ultimately results in complete failure for some conifer species and probably a growth-retarding influence on nearly all. Greenhouse experiments with additions of alkaline sand to an acid nursery soil extending over a period of 1½ years resulted in increased damping-off of all tested species; injury to *Pinus resinosa*, *P. banksiana*, and *P. ponderosa* was severe, moderate, and slight, respectively. Subsequent injurious effects on red pine were marked by stunting, chlorosis, and ultimate death of most of the seedlings; fewer jack-pine seedlings died and the chlorosis was less pronounced. Ponderosa pine on alkaline-sanded soil had good color with a slight tendency toward malformation of needles and some decrease in growth rate (fig. 1). Field experience and laboratory tests indicate that sand should not be used if random samples show that any large part of it has a pH higher than seven or that many of the particles show effervescence when treated with dilute hydrochloric or sulfuric acid. The effect of the sand on the disease hazard of a seedbed soil into which it is mixed can be predicted from the pH to which it brings the soil. This method offers the most certain way of determining the degree of safety of a particular sand. In general, the greater the increase in pH the greater the increase in disease hazard.

Seeding depth in light and sandy soils is generally greater than in heavy and loamy soils. Sowing elm seed too deeply in heavy soils sometimes results in mechanical injury to the cotyledons as the seedlings push through the soil. Such injury has been found to reduce considerably the subsequent growth of the plant and may lead to heavy losses. In the case of acorns and larger nuts, decay fungi frequently spread from seed to seed when these are planted deeply in poorly aerated or poorly drained soils, especially when sown thickly so that the nuts contact each other in the drill. This has resulted in numerous gaps in the rows. The decay of smaller types of seed in the soil is less easily detected, but it appears to be of some importance. The causal fungi have not been critically studied and they may differ from those associated with damping-off epidemics.

WATERING

First-year seedlings are surprisingly resistant to drought, but must be watered frequently during germination and thereafter at most

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nurseries during extremely dry spells. It is not harmful to seedlings to water them while the sun is shining. Actually mid-day watering on hot sunny days results in lowering soil temperature, which reduces heat injury of seedlings; however, this practice results in greater evaporation losses than early-morning or late-evening watering. This increase in water consumption might be an economic limiting factor on midday watering at nurseries dependent on city water supplies or

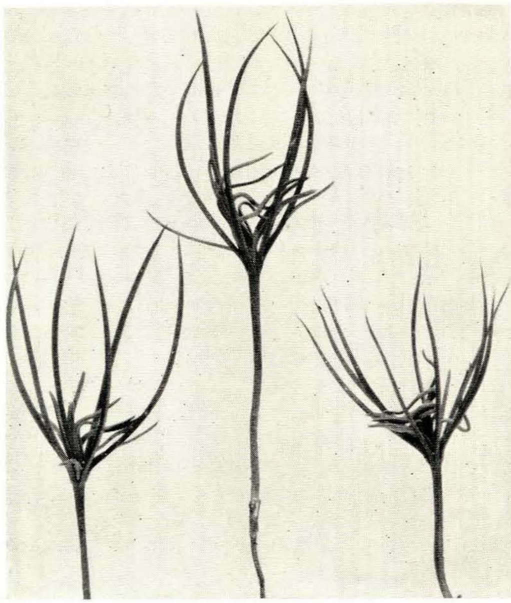

FIGURE 1.—Deformed and retarded top growth of 6-month-old *Pinus ponderosa* seedlings, resulting from excessive additions of alkaline sand to acid soil.

at places or times of water shortage. Watering late in the afternoon or after 6 p. m. usually results in drops of water remaining on needles and buds of the seedlings through the night. This moisture condition may be favorable for germination of spores and the subsequent development of top infections. Midday watering is free from this objection and reduces liability to heat injury through its cooling influence on the soil. At one nursery located on a sandy soil it was observed that the top inch of soil, in seedbeds which received noon watering, 2 hours later was 8° cooler than beds not receiving the noon watering. At places and times when heat injury is feared, as in very young seedlings on hot still days, frequent waterings are more essential than heavy waterings, since the object is to keep the surface soil cool. On soils that tend to cake, frequent light waterings at the time of seedling emergence are of considerable value, and, on beds that have been treated with acid or sulfate against damping-off. frequent rain or watering is especially essential until emergence is complete.

Watering should be less frequent but more thorough after the seedlings have passed the stage when they are susceptible to heat injury. The need for larger quantities of water accompanies the increase, in size of the individual plants and, likewise, as size of the plants increases,

the possibility of drought losses becomes greater. Moist soil in the paths or even at the surface of the beds does not always mean moist soil in the beds at the absorbing root level. To prevent drought in stock at least 2 months old, waterings should be thorough; frequent light waterings are not effective against drought for such stock and may result in poor root development. Hand sprinkling with a hose is rarely thorough enough, and fixed sprinkling systems are not always allowed to run long enough at a time to be effective. They should be checked either by measuring the water delivered in terms of inches of rainfall or by determining how far the water actually penetrates into the soil. Some very heavy losses of older stock have resulted from drought, because nurserymen depended on watering that proved on measurement to be entirely inadequate.

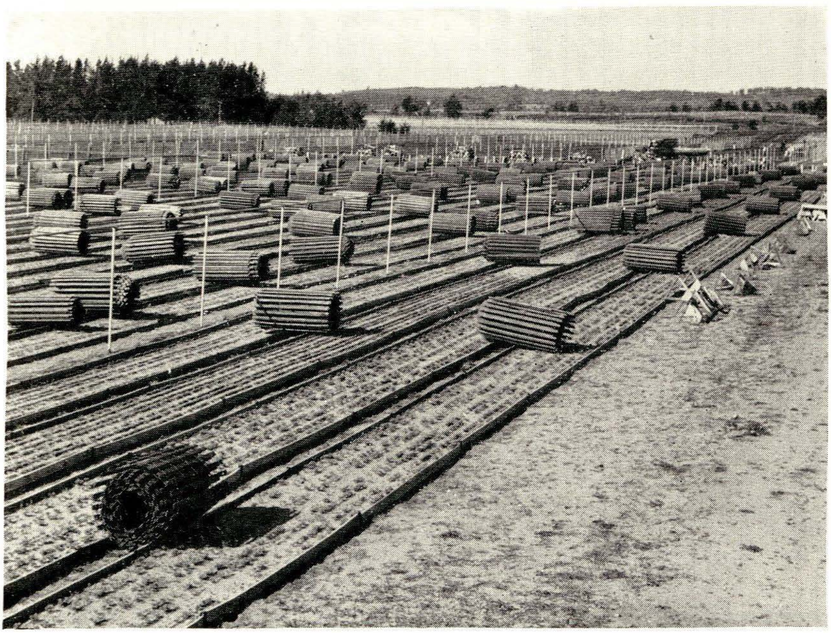

FIGURE 2.—Protection of seedlings by shading against heat and sun-scald injury, (shades removed in photograph.) (U. S. Forest Service photograph.)

Watering can be used to advantage, to keep the temperature from going as low as it might otherwise go in late spring or early fall frosts. Alkaline water should be avoided, as its continued use will lead to the accumulation of a toxic concentration of salts in some soils and through its possible influence on soil pH value to an increase in both the damping-off and root-rot hazard.

SHADING

Most broadleaf species do not need to be shaded while the majority of northern pines, firs, and spruces are liable to actual killing of the stem by heat at the soil surface, if not shaded during the first few weeks after emergence (fig. 2). Unless the weather is quite likely to

remain cool, shade frames should be in place by the time the seedlings emerge or immediately after the mulch is removed; to delay shading for even a short time has resulted in serious losses at several nurseries. Fifty-percent shade is sufficient protection at most nurseries. To be most effective, the shade frames should be set at least 18 inches above the bed; if set low or with tight board sides, the shade frames interfere with air movement and increase the disease hazard. Considerable heat injury has been known to occur on susceptible species even under standard shade where air movement was nearly shut off. When slat shade is used, the slats should run north and south if possible so that the bars of sunlight move across the bed; and the frames should project far enough to the south to keep the sun from reaching the seedlings along the southern edge of the bed. If side walls are required to exclude birds or rodents, it is safer to use screen sides rather than boards. Dangers connected with the use of freshly creosoted shades and frames are considered under "Insecticidal and Related Injuries."

The safest practice is to remove the shades in moist weather, but it is doubtful whether the advantage is sufficient in most nurseries to justify the extra labor involved. There is need for this precaution only in the exceptional nurseries where top damping-off or stem and needle diseases are important or when stands are unusually dense and weather is extremely moist.

WEEDING

Direct and indirect weeding injury to seedlings and transplants is common. On occasions where weeding operations have been delayed and the weeds have become large and dense enough to shade adjacent tree seedlings, care should be exercised in removing the weeds. The accidental and inadvertent losses of seedlings accompanying the pulling of large weeds frequently are great. Losses in excess of 90 percent have occurred during the first few days after weeding red-pine beds in which the weeds had been unmolested for 4 weeks. It is not known whether such losses of seedlings are mainly due to direct effect of the sudden exposure of the tops to the sun, to the disturbance of the roots, or to a combination of these. Possible means of avoiding such losses once the weeds are established would be through partial weeding or disposal of weeds by cutting them off near the ground. Later, when the tree seedlings become larger and the bark tissues are better developed, the weeds can probably be pulled with less damage to the roots and less danger of heat injury to the tree seedlings. Pulling large-rooted weeds in longleaf-pine seedbeds aggravates damping-off by loosening the soil around the crown of the seedlings.

In drill-sown seedbeds mechanical weeding is gaining favor with some nurserymen. A certain amount of injury to seedlings or direct cutting off of seedlings along the edges of the drills occurs in such operations. Direct losses by cutting seedlings in such operations may not be a factor of importance; however, the indirect effect of injuries to seedlings, particularly in a crop beyond the cotyledon stage, may prove to be of more importance. Pathogenic fungi can enter through injuries and may then cause the loss of seedlings from injuries that would not alone have been sufficient to kill.

FERTILIZATION AND SOIL AMENDING

While additions of fertilizers to nursery soils are frequently not only desirable but also necessary, their indiscriminate use is apt to lead to serious disease problems. When ordinary barnyard manure is used, it should be well decomposed, and application should be made several months in advance of sowing. Moderately heavy applications of chicken manure for conifers is advised against as its use has been associated with chlorosis, stunting, and root rot. In one case on acid soil the detrimental effect was relieved by applications of phosphoric acid and to a less degree with superphosphate. If the area to be sown is covered by a rotation crop, it has been shown by actual field trials that the crop should be turned under at least 1 month prior to sowing the tree seed. If this is not done, the pre-emergence damping-off hazard may be materially increased because of an overabundant accumulation of nitrogen. Nitrogenous fertilizers should be applied several weeks before seeding, since their use immediately before or shortly after seeding has led to increased damping-off losses. If fertilizers are found necessary after the seed is sown, the application should be delayed until the seedlings have developed woody stems, at which time they will be past the damping-off stage.

More is known about the relationship of fertilizer practices to conifer diseases than to those of broadleaf species. Among the inorganic fertilizers, ammonium sulfate has given beneficial results in correcting cases of chlorosis; spruces as well as pines have responded. It is most commonly used at rates of 200 to 400 pounds per acre; the smaller amount usually is sufficient and is much less apt to stimulate damping-off and root rot. As a source of nitrogen for most conifers, ammonium sulfate or phosphate is preferable to the nitrates except on strongly acid soils, since its ultimate effect is to acidify while the nitrates tend to shift the reaction in the alkaline direction. Organic nitrogen fertilizers or mixtures of ammonia and nitrates can be used if it is desired to maintain the initial pH value of the soil. Application of ammonium sulfate in solution may cause burning of needles if it is allowed to stay on them; it is best to wash it off the tops by sprinkling after an application is made.

Deficiencies believed to be due to the absence of certain microorganisms in the soil are discussed under "Mycorrhizae."

Even at nurseries where the disease is negligible on unfertilized soil, nitrogenous fertilizers must be applied with caution to species subject to damping-off, and to redcedar since these fertilizers appear to increase its susceptibility to blight. Tankage, Milorganite, dried blood, sodium nitrate, and ammonium salts have all given definite evidence on different soils of increasing damping-off of conifers. If it is necessary to add nitrogen to conifer seedbeds, it can be applied with least danger as ammonium sulfate, or perhaps still better as ammonium phosphate, in small amounts (100 pounds per acre), beginning only after the damping-off period of hazard has passed, usually about 4 to 6 weeks after emergence. The effect of such delayed applications on seedling growth should ordinarily be quite as good as if applied earlier. Phosphorus should be tried on any soil where conifer growth is very poor or uneven, especially if the poor growth bears no relation to crowding or if the stunted stock shows an unusual degree of winter

purpling. Potassium deficiency has not been known to exist to the degree of causing a real disease hazard in forest nurseries in the United States, but is said to have done so in Europe. Potassium, magnesium, manganese, and iron may be worth trying on soils where stunting and/or chlorosis are not relieved by more ordinary measures.

At some nurseries light applications of pine-needle mulch that has been in use as a soil amendment for a number of years have had no apparent effects on disease, but increases in conifer damping-off losses and black-locust damping-off caused by *Phytophthora* sp. have been associated with the incorporation of broadleaf mulches into the seedbeds. The use of charcoal, if not alkaline, to make soil lighter in texture, seems to have no effect on disease beyond an apparent increase in the liability to heat injury that would be expected from the addition of any material that makes the soil either darker or looser. For the more commonly produced forest species, lime and wood ashes should not be employed, since they tend to make the soil alkaline and thus predispose the stock to damping-off, root rot, and chlorosis. Consequently, in clearing a new nursery site, stumps and brush should not be burned on it but should be removed from the area before burning. Sugar in some indirect way has decreased damping-off of both conifers and broadleaf species on some soils, and experience on other crops indicates that other low-nitrogen organic materials may be helpful. Unrotted sawdust has no known effect on parasitic diseases and probably increases the liability to drought and heat injury on some soils, but if well-rotted and particularly if from oak it often has acidifying value and by analogy with experience of rhododendron growers and by a limited amount of nursery field experience may be expected to be beneficial. Forest humus and peat, if acid, are considered to be the safest organic materials. Some peats are alkaline and undesirable. Fertilizers and soil amendments which are beneficial to one crop species may be injurious to another. Advantages from the use of lime on some soils for many of the legumes are recognized, but if conifers are to follow, lime should not be used.

Late-season applications of fertilizers are apt to result in the stock's failing to harden off enough to be resistant to fall and early-winter freezes.

MULCHING

In northern regions with little snow, it is often necessary to mulch certain species to prevent winterkilling or heaving. Such a mulch, if it consists of materials that are inclined to waterlog and pack down, may cause molding under the mulch or actual smothering of the stock. Leaving a mulch on longer than is necessary in the spring often has this same effect. A loose, light mulch is usually safest. Care should be taken not to introduce parasitic fungi with the mulch, and practical aspects dictate that it be of such nature that it will not introduce weed seed.

TRANSPLANTING

Some root diseases may be reduced by exercising special care in transplanting. Especially careful transplanting technique, which insures the least mechanical injury to root systems, protects them while they are out of the ground, gets them back into the ground as promptly

as possible, and properly tamps them, will help prevent troubles of this nature. Topsoil loss from removal of 4-, 6-, and 8-year-old trees with balls of earth around their roots results in respective losses of 4, 6, and 8 percent of the original topsoil. Where an appreciable amount of stock is "balled" before it leaves the nursery, special consideration must be given to fertilizing practices if nutritional diseases are to be prevented. Topsoil losses are not rapid at nurseries where soil is removed from roots of stock when lifted.

ROTATION

The growing of consecutive crops of susceptible species in the same area tends to increase the disease hazard. Therefore, rotation of the species from year to year is desirable. Species especially susceptible to damping-off should be rotated with those less susceptible. Certain farm crops also appear to influence the incidence of disease in some broadleaf species. Preliminary tests indicate that damping-off of certain broadleaf forest-tree species is more severe following some legumes than cereals, such as corn or sorghum. Potatoes appear to be undesirable predecessors of ailanthus, elm, and maple because of a verticillium wilt, which quite commonly affects all these genera in the East. The verticillium disease of potato is uncommon in the midcontinental region, but other diseases of potatoes, such as rhizoctonia, may also affect seedlings of broadleaf species. So far as is known, cephalosporium wilt of corn does not affect deciduous tree seedlings.

It has been pointed out that the practice of sowing some fast-germinating truck-crop seed along with the tree seed to facilitate early weeding is inadvisable. Many truck crops are subject to the diseases that affect seedlings and may, therefore, increase losses in the latter by building up undesirable soil parasites. If such practice is desirable, it would be advisable to use a less susceptible species, such as wheat, for marking crops.

Certain species do poorly on fail entirely when grown in rotation with others. If buckwheat is grown successively for 3 or more years as a cover crop in some northeastern nurseries, the root-rot hazard for red pine is distinctly increased. Rhododendron cannot be successfully grown immediately following black walnuts. A strict crop-rotation program for disease protection should not be practiced at the sacrifice of benefits to be gained by growing pine seedlings following healthy pine transplants, as set forth under "Mycorrhizae."

DIGGING AND SHIPPING

Maximum prevention of possible infection will be obtained when digging if bruising, root splitting, and bark stripping are kept at a minimum. To avoid losses during handling, tops, especially of evergreens, should not be left very long without ventilation in warm weather. Roots must not be allowed to become dry. From the time the soil is first loosened around the roots in digging to the final planting operation, the roots of many species must be protected from sudden freezing. However, because of the danger of heating, in warm weather shipment in open trucks (fig. 3) is generally safer for evergreens than shipment in railway cars or steamship holds. In making long shipments, loose baling is probably safer than tight baling. The

practice of dipping the tops in Bordeaux mixture before packing has been suggested, but its value is somewhat questionable; it might actually cause injury if the tops remain wet. Against either top or root fungi, lime-sulfur solution is probably safer if a dip is necessary.

INSPECTION

Spread of disease, both within the nursery and to plantations, may be considerably reduced and in some cases even prevented by culling stock which inspection at lifting time shows is infected. Trees that show evidence of root decay should be discarded; likewise, southern pines that give evidence, by the readily recognizable stem swellings, of being infected by *Cronartium fusiforme* should not be sent out to

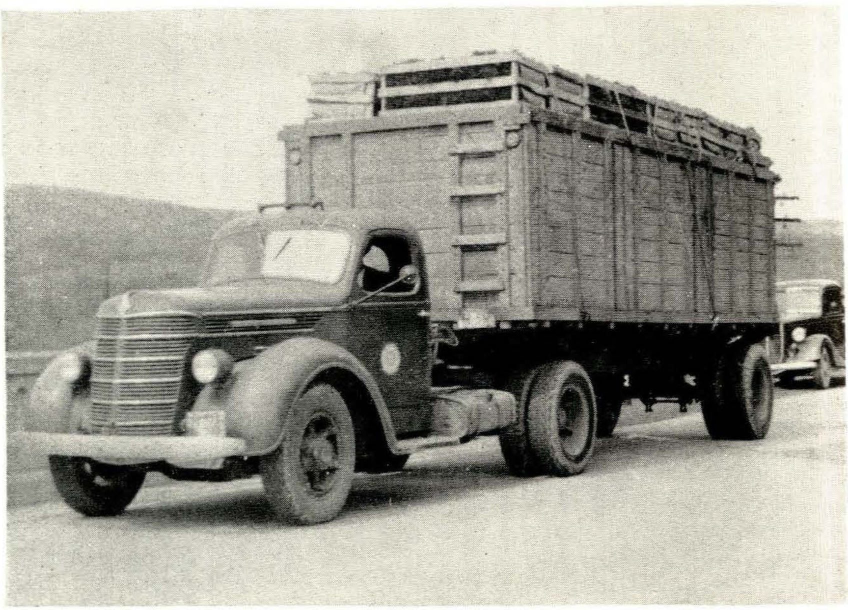

FIGURE 3.—One million 2–0 white-pine seedlings being transported in an open truck. (Soil Conservation Service photograph.)

plantations. It is also necessary to inspect when there is reason to fear that the conifers may have become infected with either mistletoe or blister rusts in the nursery, but since both of these types of disease are often invisible until some months or even years after infection, inspection is only a partial defense against them. In most cases, stock, particularly if deciduous, suffering leaf infections, should not be culled. Any nurseryman in doubt as to the proper preventive precautions to practice for a given disease may get specific advice by writing either to his State Pathologist or to the Division of Forest Pathology, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C.

SNOW ELIMINATION

Where snow is so heavy and lasts so long that seedlings mold under it before the end of the winter, there are three more or less obvious

methods of prevention: (1) Erect snow screens or plant windbreaks to keep part of the snow from drifting over the seedlings; (2) place logs in the paths and lay boards across them, providing a roof to keep the snow off the trees; and (3) sprinkle black soil over the surface of the snow in late winter to hasten its melting.

DISEASES DUE TO CAUSES OTHER THAN FUNGI

HEAT AND DROUGHT INJURY

Heat injury of young seedlings is frequently mistaken for damping-off. If examined within a day or two after occurrence, heat injury can be distinguished, at least in its best-known form, by the fact that the lesions are at, or more often just above, the soil level, they are usually very light in color, and their boundaries are sharply defined. Damping-off lesions on the stems, by contrast, commonly are extensions of infections that started below the soil surface, and the discoloration and constriction have no definite border, passing gradually over into the normal tissue. Where heat is responsible for any considerable amount of killing, lesions that tend to be one-sided will be found mainly on the south and west sides of stems, or on the upper sides of stems that are leaning over, and in parts of the beds that are especially exposed, as on south slopes. Frequent watering can give as good protection as shading, since it is primarily the heat of the surface soil that causes the burning. Shade frames when used should not be so low as to prevent air movement; low shades and tight board sides predispose to heat injury as well as to top infections. Broadleaf species are less subject to heat injury that are conifers, partly because they shade the bases of their stems at an early age. However, heat injury has been observed in the Midwest on black walnut, oak, hickory, hackberry, ash, *Morus*, soft maple, and honeylocust. Such injury had been reported from the Southwest on pecan and black-locust seedlings. Seedlings in rows running north and south are usually less severely damaged by heat than those in rows running east and west. In the latter, in some sections of the country, drying effect of hot south winds may also become severe. Older stock with woody stems may also suffer from heat, but such damage is relatively rare in nurseries. The killing takes place at the base of the stem and on many of the affected trees the lesions are limited to the south or southwest side; recovery from one-sided lesions is frequent. When girdling has occurred on larger stock, the trees may remain alive for a year and develop swollen growths above the lesion, before the starvation of the root results in its death and subsequent decay. At nurseries suffering such losses, transplant rows should run north and south, or still better, slightly west of south, in order to provide shade for the stem bases during the hottest part of the day. Where injury is apt to occur, it may pay to transplant so that the stock leans slightly to the south.

Injurious and even fatal drought conditions must be guarded against, particularly in crowded coniferous stands and on very sandy soils. In dense stands there is greater competition for water and plant foods than in medium to thin stands. This sometimes, if not guarded against, results in chlorosis and stunting, and in extreme cases in death of the seedlings. In such stands drought injury makes its appearance rather suddenly in irregular strips and patches in the interior of the

beds (fig. 4), the margins of the beds remaining unaffected. Injury is most common in dense stands that have already been stunted somewhat as a result of water or nutrient shortage. In some instances the older needles have been killed and in others the young shoots. In trees entirely killed by drought, the roots apparently die as soon as the tops. The dying of the trees in groups or streaks is sometimes mistaken for fungus injury. Top-killing fungi can cause a similar appearance, but they work under extremely wet or humid conditions and do not kill roots simultaneously. Root diseases can be distinguished from drought by the fact that they are not limited to the interior of the beds.

FIGURE 4.—Example of drought killing. Note nonproductive strip in center of 1-year-old longleaf-pine seedbed.

A permanent droop of the needles of *Pinus resinosa* and *P. strobus* has been noted in several nurseries. About one-fourth inch from the base of the needles, in the elongating and actively growing region which is enclosed by the sheath, the needle bundle was bent through an angle varying from 60° to 150° F. so that the needles pointed downward, the needles being brown and shriveled at the point of the bend but usually remaining green for some time through the rest of the length. This disease condition in nurseries is believed to be associated with drought, occurring at a time when especially rapid and succulent needle growth has taken place. In nurseries needle droop has rarely been followed by death of the affected seedlings.

FREEZING INJURY AND WINTERKILLING

While all nursery stock is subject to injury by frost or freezing, some species are more resistant than others and any species is less susceptible when it is growing slowly than when it is making rapid succulent development. Early-fall or late-spring frosts frequently cause serious injury to seedlings that are growing at the time, particularly to the youngest parts. Black locust, so injured in an October freeze, by December showed dead tips, pale-green and dry-appearing cortex in the greater portion of the stem, and often dead and brown areas of bark centering at leaf scars or wounds. Near the base of the stem in many cases, pink pustules of a *Fusarium* broke out through the bark.

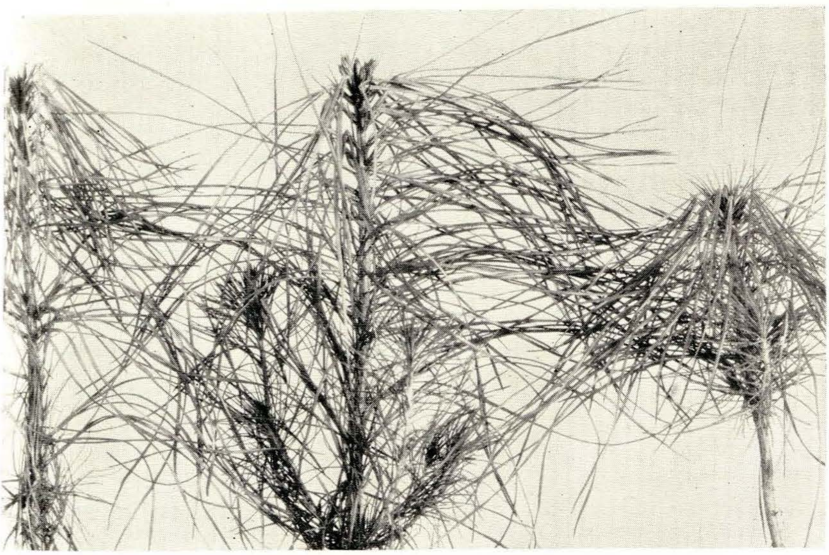

FIGURE 5.—Loblolly-pine seedlings showing needle-droop symptoms, the result of frost injury.

Below this zone infected by *Fusarium*, the root was usually healthy. This *Fusarium* is considered identical with a species reported to be associated with winter injury in Europe. Bacteria were found to be penetrating farther from the lesions than did the *Fusarium*. On nights when frost injury is anticipated it is possible to greatly reduce or even completely remove the hazard by flooding the seedbeds or running the sprinkling system. Pine-needle droop (fig. 5) of older stock has been associated with heavy frosts in a few instances.

During cold, prolonged winters or during winters with little snow, winterkilling of nursery stock sometimes is quite serious. Winterkilling is likely to be most severe where the stock is least protected by windbreaks or mulch. In pine, on the less seriously injured trees, usually some of the needles have brown tips and green bases; the general appearance of the individual plant is much as in drought injury. Large parts of the upper root systems of Oriental chestnuts suffering severe injury may be dark and soft while the stems continue for a time to have a normal appearance or to show darkening of the cambium

only, with the cortex remaining green. Oak, catalpa, and mulberry also may suffer severe injury and killing in this way. Occurrence of such losses in outdoor heel-in beds can be kept at a minimum for such species as black locust, black walnut, white mulberry, and oak by deep heeling-in in loamy well-drained soil. In the northern part of the country where low winter temperatures occur, heeling-in stock outdoors in shingletow, sawdust, coarse sand, or any such porous medium may result in severe losses. Freezing injury of Siberian elm, apparently as a result of a temperature of 15° F. below zero occurring just after the stock had been undercut but before it had been pulled, resulted in the root cortex gradually turning a brown color during the following weeks, with the stems remaining normal in internal appearance. When low temperatures may occur, it is advisable to undercut only as much stock as can be pulled during the day. Winterkilling generally appears to be the result of drying when the soil and roots are so frozen that the amount of water given off from the needles cannot be replaced to a sufficient extent by absorption from the soil. When tissues are not quite thoroughly hardened, or probably even when well-hardened tissue is subjected to the most extreme low temperatures, the crystallizing of an excessive proportion of the water in the protoplasm probably causes injury; but the obvious relation to wind exposure in most winter-injury cases indicates that water loss from the needles is the more common cause.

The roots of stock that has been injured by freezing are susceptible to attack by various fungi. Species of *Fusarium* and *Macrosporium*, that ordinarily do not appear to act as pathogens, are reported to be the ones most commonly associated with indoor-storage root rots and root molds of stock that has been injured in this way. Such storage losses may be avoided by lifting stock only when the temperature is above 30° F.

Winterkilling may be mistaken for drought killing or root rot. Careful examination is sometimes needed to determine the cause of injury. Although the cause of winterkilling and drought is fundamentally the same, there are important diagnostic differences. Winterkilling is worse in open stands, while drought is worse in dense stands. Closely sown trees protect one another from drying winds and their tops act as a mulch, protecting the soil from deep freezing. Much and frequent windbreaks are advisable in nurseries for species where there is trouble from winterkilling.

Nursery-stock losses may also result indirectly from low temperatures through soil heaving, which may cause serious losses in either seedling or transplant beds. Root injury may be so severe to either coniferous or broadleaf species that attempts to replant will fail. Occasionally soil heaving, even though not dislodging the plants from the ground, may result in their death by girdling. In such instances the roots appear to firmly anchor the seedling while the frozen crust of the soil adheres tightly to the bark and gradually breaks and pushes it up the stem for about one-fourth inch. A small amount of heaving in 2–0 stock may partly compensate for any damage by its effect in selectively eliminating weak and shallow-rooted plants. The soil heaving results from the formation of ice crystals and lenses in alternate freezing and thawing. The formation of these ice crystals and lenses is favored by clay soils and high water tables. Remedies

lie in the direction of improving soil texture by adding sand or organic matter, lowering the water table through better drainage, or mulching the beds.

DEFICIENCY DISEASES

Chlorosis and other less known or less easily recognized symptoms, such as mottling, discoloration, streaking, rosette, and malformation and dwarfing, have been found in a variety of crop plants and may be prevented or cured by adding single chemical elements. When the chemical is added directly to the soil, it may be possible that the beneficial effect is not due to the supplying of some specific element to the plant but rather to some indirect effect brought about through a change in soil conditions by that chemical.

Chlorotic and off-color pine seedlings of various ages usually exhibit rather definite characteristics which may result from numerous causes. The type of chlorosis that is perhaps most frequently encountered may be described as a general paling or yellowing in which all the cotyledons and/or needles are affected. Frequently it is difficult to tell whether this type of chlorosis is due to lack of iron or nitrogen; sometimes it appears to be due to some obscure or little-understood cause. If the seedlings are on a rather heavy alkaline soil, the cause is likely to be a deficient or unavailable supply of iron. If the trouble is limited to centers of crowded stands, and particularly if it is in spruce, the cause is probably a lack of nitrogen, but a somewhat similar yellowing in crowded parts of beds may result from water deficiency. Excess nitrogen also may cause yellowing which might be less noticeable in the crowded parts of the beds. In alkaline soils, and particularly if much lime is present, iron deficiency causes chlorosis in many broadleaf species. This is probably the commonest of the deficiency diseases. Black locust and hardy catalpa appear to be quite subject to it, while Siberian elm is reported among those least subject.

Generalized chlorosis may in some cases be due to infection with root-rot fungi, or to root reduction in pruning or digging. Transplanting chlorotic seedlings has sometimes corrected the condition.

A somewhat different type of chlorosis frequently occurs on 1–0 pine in the Central and Southeastern States, especially on shortleaf but also on loblolly pine. This latter type of chlorosis is characterized by a tendency to affect mainly the youngest needles. The condition is temporary, usually lasting 1 to 3 weeks. There is little or no top growth during the period of chlorosis. The cause is unknown; it may coincide with the initial stages of mycorrhizal or peseudomycorrhizal infection.

A premature or late-summer purpling of various species of pine seedlings is believed to be indicative of a phosphate deficiency which in some cases has been associated with chlorosis. This is particularly true if the seedlings show stunting along with the purpling. Phosphate-deficiency symptoms appear to be more pronounced on the older needles, the discoloration beginning on the lower cotyledons or needles and progressing upward, the needles affected first sometimes dying before the youngest needles are affected. Chlorosis due to excessive applications of nitrogen fertilizers may be corrected in some soils by the addition of phosphoric acid. In longleaf pine a deficiency of

phosphate may be indicated by the fascicles containing only two needles instead of the usual three; the needles have a normal color.

Instances of yellow seedlings, believed to be of less frequent occurrence, have been associated with various causes. Magnesia and potash treatments of yellowed conifer stock have been reported to correct the discoloration in some instances, and manganese sulfate may also prove to be beneficial. Excessive shading and watering may induce chlorosis. The reduction of watering or shading of stock showing such effect should be gradual for the greatest safety. Seedlings in this condition are not only more liable to drought and heat injury but are also more susceptible to needle and stem diseases. In one nursery a case of chlorosis of an unusual type was found to be caused by illuminating gas that had escaped from a pipe line that passed beneath some of the seedbeds. The roots of seedlings affected by this gas may develop hypertrophied lenticels. One type of discoloration in which pine seedlings showed needle redness or died has been associated with a high chlorine content of the soil. A description of foliage discoloration associated with some insecticides is given in "Insecticidal and Related Injuries."

Acid soils, particularly peat soils, sometimes produce much better plants if minute quantities of copper are added to the soil. The addition of small quantities of zinc has been found to relieve growth abnormalities in a number of hosts, and in rare cases the addition of boron has been reported helpful. All three of these are very toxic if applied in excess and should be used only in small plot tests until their effects on the plants under local conditions become known. Zinc deficiency, like that of manganese and iron, can be tested by spraying suspected plants and comparing their development with unsprayed plants.

Deficiencies in the ordinary fertilizer elements are most likely to occur on light sandy soils, where seedlings are dense. A marginal amount of a particular element may become submarginal if other elements are added in excess in fertilizers or amendments. In order to keep the damping-off hazard at a minimum, applications of organic matter to correct chlorosis, particularly if poorly composted or containing nitrogen in amounts greater than 200 pounds per acre, should be made several weeks in advance of seeding, or, if the nitrogen is applied as a side dressing, not until the stems have become woody.

Without knowledge of soil conditions and the species involved, no specific advice can be given for correcting chlorosis. Where possible, the cheapest procedure is to locate the species that are subject to chlorosis in areas in the nursery which are acid or least alkaline. On neutral or alkaline soils it is not known whether the yellowing results from an unsuitable pH, unavailable elements, or is a combination of these two factors. Nurserymen can usually solve mineral-deficiency problems for themselves by making small-scale experimental tests. Suggested chemicals and rates of application for small-scale experimental tests are given in table 2.

Following the application of phosphoric acid, ammonium sulfate, manganese sulfate, or ferrous sulfate, applied as surface-soil treatments, the trees should be thoroughly watered to wash the material off the tops. Ferrous sulfate used as a spray should not be washed off the

seedlings. The seedlings will usually respond within at least a week or 10 days to ferrous sulfate spray or ammonium sulfate if either iron or nitrogen is lacking.

TABLE 2.—*Suggested chemicals and rates of application for small-scale experimental tests*

Chemical	Usage	Suggested rate of application
Ferrous sulfate	Spray	1 percent solution.
Do	Surface soil treatments	½ and 1 ounce in 1 pint of water (per square foot of bed). On soil with pH of 8 or above, more will be needed.
Aluminum sulfate	do	½ and 1 ounce in 1 pint of water (per square foot of bed). On soil with pH of 8 or above, more will be needed.
Treble-superphosphate	do	200, 400, and 600 pounds per acre.
Phosphoric acid	do	1/16 and ⅛ fluid ounces in 1 pint of water per square feet.
Ammonium sulfate	do	1/10 and ⅕ ounce in 1 pint of water per square foot.
Manganese sulfate	do	50 and 150 pounds per acre.

Soil acidification with sulfur is also a feasible remedy. Ferric citrate, ferric tartrate, and ferrous sulfate in sprayings at concentrations of 7 and 10 percent probably will burn the leaves of catalpa but may have no apparent detrimental effect on the black-locust seedlings; applications of these chemicals at 1, 3, and 5 percent usually are not dangerous, but not over 1 percent can be advised. Iron hunger can also result on soils which are too rich in manganese. On calcareous soils, on the other hand, chlorosis may occur which sometimes can be corrected by the addition of manganese. Sometimes deep cultivation may be helpful in heavy soils in correcting chlorosis, the benefit possibly being brought about through increased soil aeration.

ROOT WARTS

Rough reddish-brown protuberances on the roots of conifers are sometimes disturbing to nurserymen. These warts, which occur especially in wet soil, may be found on both tap and lateral roots to as deep as 14 inches beneath the surface soil. These structures are greatly enlarged lenticels. They vary in size from small circular areas to patches nearly encircling the larger roots, where two or more lenticels are adjacent. Enlarged lenticels are more common on poorly rooted transplants or seedlings than on those with well-developed roots, and are regarded as symptoms of poor aeration or of insufficient root surface. No actual losses have been associated with this abnormal root condition. This disturbance is apparently much less frequent in occurrence on broadleaf than on coniferous species. It presumably may be decreased through better soil aeration and drainage.

NEMATODE INFESTATION

Nematodes, commonly called eel worms, present a considerable problem, especially in the South, where the root-knot nematode is usually spread. The infestations by this species appear to be related to soil texture, the most serious cases being associated with porous or sandy soils. The possibility of such infestation occurrences may be reduced by careful inspection of prospective nursery sites. In such inspections, the roots of crops or native plants can

be examined for indications of relative occurrence of nematode root galls. While catalpa, mulberry, black locust, and redbud are among the hosts most frequently reported infected, most broadleaf species are susceptible to infection by nematodes. If there is any doubt as to whether black locust and other legumes are infected or if the swellings on the roots of the stock are the beneficial bacterial nodules, a pathologist or nematologist should be consulted prior to either culling or distributing the stock. Nematodes are not of any general concern in the production of coniferous stock. However, they have been associated with diseased conifers in forest-tree nurseries on several occasions. Nursery stock of any species that is badly infected should be culled at time of lifting to reduce the spread from the nursery to the field.

DODDER

Dodders (*Cuscuta* sp.) are flowering plants that grow parasitically on many hosts. Dodder has caused some losses of seedlings of broadleaf species but in general appears to be of no importance in coniferous stands. It has been found on black locust, white and green ash, cottonwood, black walnut, red and white oak, willow, and desert-willow. It spreads by seed or by vine. It appears as a fine, yellow vine, sometimes growing so densely as to completely cover the tops of the host seedlings. The bulk of the dodder vines may be removed from the seedlings with a rake similar to a currycomb which may be made by driving nails through a board to which a handle is fastened. However, unless all parts of the dodder vines that are coiled around the seedlings are removed by hand, the pest is apt to reestablish itself in a relatively short period. Sometimes dodder spreads from native vegetation at the margins of the nursery. Cleaning away such plant growth, thereby creating a barren border around the nursery, should be somewhat effective in preventing infestations. Dodder seed frequently is a contaminant of agricultural seed which may be used for rotation crops. It is, therefore, always advisable to use clean seed.

EXCESSIVE CONCENTRATIONS OF INSECTICIDES AND FUNGICIDES

Various arsenic compounds have been employed in the past in coniferous seedbeeds for the control of white grubs and the Japanese beetle. Frequently the rate of application was beyond the arsenic tolerance of the tree species. A given rate of application may be lethal to the stock on one soil and on another soil exert no detrimental influence. Paradichlorobenzene also has been observed to cause injury to young conferous seedlings, but the danger of injury with this compound is less than that associated with the use of arsenicals.

In conifer seedbeds recently treated with arsenic, emergence is reduced and surviving seedlings are stunted. Such seedlings and older stock transplanted from untreated areas to sections previously treated with arsenic are characterized by the progressive burning of the needles from their tips back, the extent or degree of burning seemingly dependent upon the amount of arsenic used. In the early stages of injury there is a distinctly reddish tinge in the affected needle tips. Sometimes in arsenic-treated areas the root system is not as well developed as in untreated areas.

No general practice is known that will free the soil of toxic dosages of arsenic, but there are several treatments which have given favorable results. Any one or all of these treatments may prove to be entirely unsatisfactory on some soils and should, therefore, be experimentally tried in small-scale tests before being applied over a large area. The application of phosphates has given freedom from arsenic injury for some species on certain sandy soils. Treble-superphosphate or phosphoric acid is suggested for such tests; the form in which the phosphate is applied does not appear to be important. The effective rate of application would have to be experimentally determined as it would be dependent not only upon the chemical and physical properties of the soil but also upon the amount of arsenic that had been been applied to the area and on the plant species to be grown. Ferrous sulfate has been sucessful on some soils, supposedly through the iron tying up the arsenic in an insoluble form. The addition of various amounts of green manure and poorly rotted barnyard manure one season prior to using the area for tree-production purposes is also worth trying. The manures act both as a stimulant to microflora activity, some of which act on the arsenic compounds (a slow process), and to increase the colloidal content of the soil which in turn would result in greater absorption of the arsenic.

Semesan, a phenol-mercury compound, is another material which is injurious to conifers, when used in excess. Pines and spruce, both fairly susceptible to excesses, may be stunted and the needles may turn yellowish-green. A heavy seed-dust treatment with New Improved Ceresan will cause stunting with some chlorosis and purpling on some soils.

Cyanogas and carbondisulfide are insecticides that in quantity will kill conifers.

Seedlings may suffer serious injury where recently creosoted boards are used along the sides of the beds or as shade frames. The young trees nearest the sideboards may die, while those somewhat more removed will be severely twisted and stunted. Use of recently creosoted shades may result in rain or artificial watering washing enough of the creosote onto the seedlings to cause injury. Such injury is characterized at first by a water-soaked appearance of the basal half of the needle which is followed by a shriveling of the needle. In the cases of more extensive injury, the upper part of the stem shrivels also and in many instances the affected seedlings ultimately die.

Mention is made of poisonous gas fumes under "Selection and Preparation of Nursery Sites" and to illuminating-gas injury under "Deficiency Diseases."

NONPARASITIC GIRDLING

Seedlings that have developed woody stems sometimes show narrow rings of dead bark at or about an eighth of an inch above the soil surface. This ultimately results in the death of the seedlings, though often not until several months later, and after there has been considerable increase in size of the stem just above the girdle. This type of injury is referred to under "Heat and Drought Injury." This same type of injury on conifers can be caused by soil heaving. When large hardwood stock shows recent nonparasitic girdling, it would be pos-

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sible to stimulate recovery by shoots from below the girdle, if the tops are cut off without waiting for them to die.

Girdling by insects may be confused with heat injury, especially if some time elapses between time of injury and date of observation; one case of insect injury is mentioned under "Locust." A recognized fungus injury to such a localized zone is described under "Maple;" the fungus collar rot described under "Oak" is easily distinguished from nonparasitic troubles.

MECHANICAL INJURY

Mechanical causes of loss are numerous and varied. Likely times for such losses to occur are during the processes of removing mulch, burlap, or other covering material from the seedbeds during cultivation and again during the transplanting of the stock. Seedlings may also suffer severe mechanical injury if a hard crust is formed on the seedbeds at time of emergence. Injury and loss of seedlings due to birds as well as to forks and rakes at time of mulch removal are not uncommon, and occasionally the stems are injured by transplant boards. Insects often cause injury that may be confused with damping-off or mechanical injury. Severe loss in both seedling and transplant stock has been recorded following hailstorms. Lightning, like hail, an uncontrollable natural phenomenon, causes occasional losses in nursery seedbeds. Plants killed by lightning show the effects at the time of or very shortly after the electrical discharges. The appearance of the trouble simultaneously on all affected plants and its limitation to one or a few definite patches are aids in recognizing lightning injury. Mechanical losses resulting from improper or careless weeding are discussed under "Weeding." In addition to direct loss of trees from mechanical injury, wounds increase the loss hazard through affording a pathway for the entrance of fungi and bacteria.

FUNGUS DISEASES OF BROADLEAF SPECIES

TYPES OF DISEASES

Seed Problems

Seed may deteriorate or decay in storage or transit unless favorable moisture, aeration, and temperature are maintained. In general, low storage temperatures and a humidity too low to allow superficial mold growth can be said to be desirable, but the optimum temperature and moisture will need to be determined separately for each of the species with which trouble occurs. The most favorable degree of aeration varies from none to forced ventilation, depending on species and whether the seed is or is not in sweat. Elm seed has been satisfactorily overwintered in airtight containers kept at about 38° F. By this method the viability of the seed is retained and the growth of molds is reduced to a minimum. This practice may be advantageous since good local seed crops are not always available from year to year. Furthermore, it has been found that American elm seed did not germinate well at a soil temperature of about 60° F., near maximum germination being obtained at temperatures of 70° to 90°. Soil temperatures of 80° and above accelerated germination of desertwillow. Less extensive tests indicated germination of caragana was favored by a temperature of about 90°. The germination of Siberian elm appar-

ently was not adversely affected by soil temperatures ranging from 60° to 90° and from 70° to 90° for black locust. Other temperature studies have shown boxelder germination to be favored by temperatures fluctuating from 50° at night to 70° during the day, but adversely affected by temperatures fluctuating from 68° to 86°. Wild plum gave 86 percent germination at a constant temperature of 50°, but only 26 percent for fluctuating temperatures from 50° to 77°, and 13 percent from 68° to 86°. Nurserymen should take soil temperatures into consideration in their sowing schedules, since anything that interferes with the prompt germination of seed may increase the danger of pre-emergence damping-off.

Seed rot during stratification may cause considerable loss, but has not been commonly reported. The heating of seed during stratification in peat moss has also given nurserymen considerable concern. Drupaceous seed, such as Russianolive and hackberry, is especially prone to heat when stratified. Depulping the seed has been of some benefit but is expensive and is sometimes injurious to the seed. Treatment of peat with 1–100 formaldehyde has markedly retarded heating for a period of 2 months and increased hackberry seed germination from 16 percent in untreated peat to approximately 50 percent for the seed in the treated peat. Similarly, Russianolive seed stratified in treated peat gave 39 percent germination while that in untreated peat gave only 3 percent. Further mention of stratification, scarification, and hot-water seed treatments is made under "Locust."

Damping-off

Both pre-emergence and post-emergence damping-off losses have been frequent with some deciduous species. Most of these losses occur just prior to or within 3 weeks after emergence and are due to soil-inhabiting fungi. Pre-emergence losses cause gaps in drill rows that othrwise would show a good stand. Examinations of the seed in these failed spots (gaps) frequently show that they are rotted or that fungus infection took place shortly after germination and destroyed the radicle. Other causes, such as excessive heat, drought, birds, insects, or sowing too deeply, may also cause similar failed spots in the drill rows.

Typical post-emergence damping-off of broadleaf species is known in two forms: The younger seedlings wilt over at the ground line, and plants with less succulent tissues remain erect and dry up. Examinations of damped-off seedlings will show that at least a part of the roots and stem are decayed. The species in which these losses are usually most severe are American and Siberian elms, black locust, tulip-tree, and desertwillow. Other species, such as green and white ash, caragana, mulberry, hard and soft maple, osageorange, buffaloberry, and *Prunus* sp., also occasionally damp-off. No evidence of any association of damping-off of broadleaf species to degree of soil acidity has been observed except possibly in black locust.

While several damping-off control methods have been tried, a completely satisfactory one for broadleaf species awaits further development. Seed dusts, such as zinc or red-copper oxide and powdered Bordeaux, are sometimes effective in preventing pre-emergence losses, and tests so far indicate that these dusts can be applied at the rate of one ounce per pound of dry seed. Copper oxide, while giving very

good results at some nurseries, may cause injury if used during abnormally hot weather. The practice followed by some nurserymen of soaking the seed overnight immediately prior to sowing is believed to decrease pre-emergence losses by speeding up germination.

Formaldehyde soil treatments may be used in seedbeds to reduce damping-off losses. Trials so far indicate that a fair degree of control may be anticipated with a minimum injury hazard, when the commercial (40 percent) formaldehyde is applied at the rate of 1/4 fluid ounce in 1 pint of water per square foot of seedbed area, 6 days prior to seeding. If the soil is quite warm, seeding might be safely done 4 days following treatment; but if the soil is cold, probably 10 days should be allowed to elapse. To test formaldehyde-treated soil with reagents several methods are now available, which indicate the period of time necessary to wait before sowing. If formaldehyde soil treatments are contemplated, it is suggested that time may be saved and better results obtained if a pathologist is called to give detailed advice in making the treatment.

Recently sphagnum moss has been reported as giving good control of damping-off for a number of non-forest-tree species under greenhouse and hotbed conditions. At one nursery, where pines were subsequently grown and where only a low percentage of damping-off occurred in both the amended and unamended soil, sphagnum moss worked into the soil was followed by increased late-summer drought losses. Despite this possible disadvantage, available data indicate that at nurseries where the damping-off hazard of broadleaf species is high, establishment of small-scale control tests with sphagnum moss is merited.

There is no known dependable soil disinfectant that can be used safely after germination has started. However, for cases where infection obviously attacks above the ground line while the roots are still sound, Bordeaux mixture has been successfully used as a spray for controlling damping-off of certain species of broadleaf seedlings after germination. Greatest advantage is to be expected only where the spray is applied just as the seedlings are emerging. Rather consistently good control of black locust seedling damping-off caused by *Phytophthora* sp. has been obtained with this spray. Time and rates of application are given under "Locust." Organic mercuries and copper oxide sprays may also be worth trying at the beginning of damping-off epidemics in the strengths advised by the manufacturers. More specific information on damping-off control measures is given under the various hosts.

Root Infections

A root disease caused by *Phytophthora cinnamomi* has been found in several nurseries in the East and South. It has been known to attack paper and European birches, black walnut, black locust, red and chestnut oaks, American and Asiatic chestnuts, chinquapin, and Oriental planetrees of various ages, as well as several conifers. The disease has occurred mainly in poorly aerated soils. For most of the broadleaf species the fungus primarily attacks the taproot producing a soft rot at the tip of the root in fleshy species and in others a dry rot. It sometimes forms irregularly shaped lesions, brown to black, at or just above the soil surface. The seedling may be killed, or the injury may be limited to the lower part of the roots. It sometimes

kills trees in plantations of stock from infected nurseries. Therefore, distribution of stock from nurseries where the fungus is known to be present should be restricted to the same general region and preferably to well-aerated soils. Specimens collected for diagnosis should be protected from drying; positive determination can be made only by cultures obtained from infected fresh material.

Texas root rot, due to *Phymatotrichum* (*Ozonium*) *omnivorum*, has a very wide range of hosts among species used in windbreak and erosion-control plantings, especially in the Southwest, as well as among cultivated crops and weeds. Grasses and other monocotyledons are not seriously injured. It is potentially very harmful if introduced into field plantings in areas where environmental conditions are favorable. The active known parasitic range of the fungus is southern Oklahoma, Texas, New Mexico, Arizona, Utah, and southern California, and it is generally agreed that if introduced in the Central or Northern States the winter temperatures would prevent it from being a serious problem. However, fungi frequently develop resistant forms when placed under normally adverse environmental conditions, and it would be unwise, therefore, to make shipments of seedlings infected with Texas root rot into uninfected areas, even in the North. The geographic range of Texas root rot has not been completely worked out, but it is possible to make surveys of questionable areas to determine its presence. No nursery should be established in the Southwest without adequate information as to whether the immediate vicinity is free of this root rot. Its damage is mainly limited to neutral and alkaline soils. In infected localities production on soils with a pH value above 6.5 should be limited to only the least susceptible species.

The shoestring fungus, *Armillaria mellea*, is another serious root parasite. While it is not as restricted in geographic range as the Texas root rot, it is commonly localized. Plant pathologists can usually detect its presence by examination of native and cultivated vegetation.

There are a number of weak parasitic root fungi that have not been studied. Diseases which harm only the deepest part of the root in the nursery may conceivably accomplish a beneficial root pruning rather than any real injury. Winter root rots are sometimes difficult to distinguish from the direct effects of unusual freezing, or from infections which can operate only following preliminary winter injury. The chalaropsis root rot of Chinese elm and the fusarium and macrosporium root rots of black locust, osageorange, Chinese elm, black walnut, Russian mulberry, and burr oak have been reported for stock in storage. The development of the latter rots has been found to be favored by exposure of plants to freezing or below-freezing temperatures during periods of lifting or transit.

Root rots of unknown cause, perhaps due to *Fusarium*, have been found locally troublesome in the Great Plains region on caragana and Chinese elm and in Texas on black locust. Exotics may be expected to show considerable susceptibility to some American fungi that are negligible in their effects on our native hosts.

Nitrogen nodules on leguminous species, absent from honeylocust, Kentucky coffeetree, and redbud, but present outside of the *Leguminosae* on alder, are generally supposed to be beneficial, but benefit

cannot be universally assumed in view of recent findings with herbaceous legumes, that indicate that some such infections may actually be harmful. More specific statements relative to the more serious root infections of broadleaf species may be found under the various hosts under "Diseases of Specific Hosts."

Crown-gall and nematode root knot, the latter especially in the South, require careful attention at some nurseries. The latter subject is further discussed under "Nematode Infestation."

Top and Stem Infections

Top infections of very young seedlings have caused heavy losses in a few places where the soil was not well-drained or where extremely wet weather prevailed at emergence time or shortly thereafter. Such losses have been negligible in most nurseries and will probably continue to be rare or sporadic. One of the better known cases is described in more detail in connection with black locust as due to *Phytophthora parasitica*, but many other hosts including several other legumes and species of *Nyssa*, *Cornus*, and *Prunus* were involved in an epidemic in a Missouri nursery. It appears that the omnivorous *P. cactorum* is responsible for some of this damage. *P. parasitica* is favored by warm weather, while *P. cactorum* has been known to work at rather low temperatures. Ventilation and drainage, and three or four sprayings with Bordeaux mixture at 2- or 3-day intervals, starting, when the seedlings first begin to come through the soil, are most promising control measures. A 4–6–50 Bordeaux mixture has generally proved to be harmless to *Prunus* and most other species requiring spray treatments, although at one nursery 4–6–50 Bordeaux severely burned cherry seedlings.

Top wilt epidemics are ordinarily of brief duration, and it is possible to safeguard a nursery against heavy losses by distributing sowings through several weeks. Then when an epidemic occurs, only a part of the seedlings are likely to be at a susceptible age. However, in nurseries where past experience shows top wilt to be serious, it would be well to make a preventive spray program part of the regular nursery schedule and not to wait until the wilt appears before starting to spray.

Vascular wilts are characterized by a discoloration, frequently brownish, in the vessels of the xylem or the parenchyma cells immediately bordering the vessels. The discoloration is similar to that associated with *Verticillium* in maple, elm, and ailanthus or with *Cephalosporium* and *Graphium* in elm. These are discussed further under "Maple" and "Elm," respectively. A similar wood-darkening trouble due to *Ceratostomella* in sycamores has yet to be recognized in nurseries. A wilt of sumac has been observed in the Midwest but is of relatively little importance.

Sore-shin

Rhizoctonia frequently has been found attacking stems of black locust, ash, cherry, and tulip tree seedlings; attacks on other broadleaf species have not been so numerous. This disease has the same characteristics on broadleaf species as are described for it on conifers under "Sore-shin." Moist but not wet conditions appear to be most favorable to the development of the disease. In central and Atlantic Coast States development and spread of the disease has been checked

in drill-sown seedbeds by cultivating in such a manner as to turn the soil away from the base of the seedlings. It is believed likely that applications of 4–4–50 Bordeaux mixture to the stems of seedlings will be beneficial in reducing spread of the disease in some sections of the country.

Leaf Infections

Losses from leaf diseases are of greater economic importance on broadleaf species than on conifers. Species of *Prunus*, *Fraxinus*, *Morus*, *Cornus*, *Malus*, and *Crataegus* are the ones that have been most regularly affected. Severity of these diseases varies from year to year. Leaf epidemics that come early in the season, particularly in the northern or high-altitude sections of the country, cut down the size of the stock, making it unusable for an additional year; besides the increase in cost of production, the nurseryman runs the risk of winter losses. In one midwestern nursery only 13 percent of badly leaf-spotted white ash, which were left for the second year's growth, survived the winter. Infection occurring at any time, if it results in partial defoliation, may reduce food storage and render the seedlings more difficult to establish when transplanted.

Leaf diseases of broadleaf species are generally spoken of as "leaf spots," "leaf blights," or "mildews." Fungi and bacteria are responsible for these diseases. Both fungus and bacterial leaf diseases can usually be controlled by spraying with Bordeaux mixture, although for powdery mildews sulfur may be found to be more effective. Generally by the time powdery mildew, commonly reported on oak and catalpa seedlings, has become conspicuous, it is too late for control measures to succeed. However, finely ground sulfur, mixed in the proportion of 1 to 10 with talc, hydrated lime, or other flux material and dusted on at the first appearance of the mildew, has been reported as preventing further spread.

Methods for obtaining satisfactory control of leaf diseases may vary in different sections of the country. For example, applications of fertilizer to ash in Atlantic Coast States have given best control of the ash leaf disease, whereas either 4–6–50 or 3–4–50 Bordeaux mixture has given good results in Iowa. Copper phosphate and flotation sulfur, in cases where there is no liklihood of extremely high temperatures, are possible substitutes for Bordeaux on sensitive species. In general, the limited experience with Bordeaux on forest and ornamental species has given better results than sprays having some form of sulfur as an active consitutent. Commercial lime sulfur solution, 1 part in 33 of water, has proved very harmful to cherry and has defoliated sugar maple in a nursery subjected to only moderate temperatures. Ericaceous plants have been known to be seriously injured by sulfur sprays. Further details of these diseases and their controls are given under the respective hosts. In drier sections of the country, insufficient water to maintain growth appears to predispose the seedlings to infection by leaf disease fungi. Waterlogged soil may have a similar effect on some species.

Molding and Decay in Storage and Transit

Heating of nursery stock when tightly packed is sometimes actually due to the heat developed by the plants themselves and sometimes to fungi that have developed in the bundles of storage piles. In either case the obvious remedy is to keep the temperature down by allowing

as much ventilation as is consistent with protection against drying out.

The molds that develop conspicuously on the bark of stock in storage are often superficial and harmless. Generally the green and blue molds that develop on injured parts of the plants are not serious except on the infrequent occurrences where they form mats which may result in heating or smothering of the stock. Deterioration or fungus decay of stems of plants in indoor-storage frequently is the result of having lifted and stored stock with immature or succulent tops or stems that have been injured in some way, such as by freezing.

The winter storage rot (*Chalaropsis thielavioides*) of the roots of Siberian elm is discussed under "Elm."

DISEASES OF SPECIFIC HOSTS

Ash

A leaf disease of ash species is common in nurseries and frequently causes severe losses, especially in northern nurseries. This disease has been referred to by some nurserymen as "leaf rust;" this is a misnomer as the organism causing this disease is not related to the group technically known as the rusts. The fungus most generally associated with this leaf disease in nurseries is *Marssonia fraxini*. Initial development of the infection is difficult to detect. The first symptoms generally appear on the upper surface of the leaves as tiny gray dots. These dots later enlarge and may coalesce. On the under side of the leaves small globose pustules appear from which grayish white masses of spores develop. These spores may be spread by rain, wind, and insects to other seedlings where, if conditions are favorable, new infections develop. The fungus is known to overwinter on old infected leaves and has been found on seed wings.

This disease causes premature defoliation and results in reduction in growth of green-ash seedlings. Under favorable conditions in northern nurseries green ash is not a rapid grower, and premature defoliation frequently necessitates holding the seedlings in the nursery an extra season to obtain stock suitable for field planting.

Control methods that give best results vary from section to section of the country. In the Prairie States intensive flood irrigation, combined with applications of 4–6–50 Bordeaux, gives good control, while in Minnesota, Iowa, and Missouri spraying ash seedlings with 4–6–50 or 3–4–50 Bordeaux (using hydrated lime) at intervals of 2 weeks has given good control of the disease. A 2-percent solution of lime sulfur has also given good control. In applying either of these sprays care should be taken to see that all of the foliage is adequately covered. For the spray to be effective it is essential to start the spraying soon after the seedlings emerge. Where this disease has given trouble in Atlantic Coast States, it has been found in some nurseries that addition of an organic fertilizer prior to seeding or applications of nitrate of soda or other fertilizers containing an equivalent amount of nitrogen applied at the rate of one-tenth ounce in 1 pint of water per square foot of seedbed area will enable the stock to outgrow obvious ill effects of the disease (fig. 6). In applying the water solution of nitrate of soda, care must be taken not to get the solution on the seedlings as it will

injure them. By applying the solution with a spray can from which the flow of the fertilizer solution can be directed onto the soil between the seedlings, applications may be made without danger of chemical injury. The fertilizer can also be applied dry, but beneficial results are somewhat slower in becoming evident.

Sore-shin has been reported on ash seedlings in many nurseries. However, in most cases the disease does not cause serious losses. A more complete discussion of this disease is given under "Sore-shin."

Puccinia peridermiospora, a true rust, has been reported in nurseries but has not caused appreciable losses. The disease on ash seedlings is characterized by swelling on twigs and petioles with the affected leaves becoming distorted. Later, bright orange "cluster

FIGURE 6.—Differences in incidence of leaf disease (*Marssonia fraxini*) and the relative growth of the seedlings associated with fertilization of 1–0 white-ash seedlings. Left, unfertilized sparse stand of small plants, the leaves of which are heavily infected. Right, dense, vigorous stand of seedlings with few leaves infected; fertilized with ammonium sulfate at approximately 270 pounds per acre after stock had developed woody stems.

cups" of spores appear on these areas, and it is usually at this stage that the disease comes to the nurseryman's attention. The marsh and cord grasses (*Spartina* spp.) are the alternate hosts for this rust. Eradication of the alternate host or periodic cutting of these grasses in the vicinity of the nursery should reduce the infection hazard.

Catalpa

Catalpa has been attacked occasionally by parasitic fungi in nurseries. However, especially in the southern and eastern parts of the United States, it has frequently been infected with nematodes. (See "Nematode Infestation.") While powdery mildews frequently are found on catalpa leaves, they rarely have been reported as decreasing the value of the stock. Control methods which should be helpful at nurseries in the event of an epidemic of powdery mildews are discussed under "Leaf Infections."

Cherry

A "shot-hole" or leaf-spot disease caused by *Coccomyces lutescens*, occurring on wild black cherry (*Prunus serotina*) and chokecherry (*P. virginiana* and *P. melanocarpa*) has caused considerable damage in nurseries. The disease usually makes its appearance on the foliage as small circular spots, varying in color from a light yellow to a purplish or reddish-brown. The affected parts of the leaves die and eventually turn brown. Sometimes the dead tissue is separated from the rest of the leaf and drops out, producing the condition frequently referred to as "shot hole"; more frequently, however, on young nursery seedlings the dead tissue does not fall out. When numerous individual infections occur on a single leaf, several spots may coalesce, forming a large, irregularly shaped area of dead tissue. This latter condition is sometimes incorrectly referred to as "leaf rust." This disease, however, is not one of the true plant rusts and no alternate host plant is necessary in the life of the causal fungus. Heavily infected leaves frequently turn yellow before they drop. This has led some to refer to the disease as "yellow leaf." Another sign of the disease that is usually evident, especially in humid weather, is the presence of small droplets of a jellylike substance on the "spots;" most frequently these are found on the under side of the leaves, but occasionally they occur on the upper side of the diseased tissue. These droplets are masses of spores which serve to spread the fungus and start new infections on the same leaf, on other leaves of the same plant, or on other plants.

The control methods given for the ash-leaf disease under "Ash" are equally applicable to this disease. However, where Bordeaux spray is used the first application should be made with a 2–3–50 mixture and the subsequent ones with 4–6–50. Under climatic conditions encountered in West Virginia, Bordeaux is not advised because of repeated serious injury at one nursery in that State with 2–3–50 mixtures. At one nursery, in addition to nitrate of soda, treble superphosphate as a side dressing at the rate of 200 pounds per acre has given sufficient growth stimulation so that the seedlings outgrew all obvious ill effects of the disease.

Wild cherries in nurseries are also subject, though less commonly, to another leaf-spot disease which, however, is caused by a bacterial organism (*Bacterium pruni*) rather than a fungus. Roundish or irregularly shaped spots appear on the leaves. The diseased tissues shrivel and finally drop out, leaving a "shot hole." Not infrequently spots along the margins of the leaves coalesce, giving them a blighted appearance. The control suggestions for the fungus-induced leaf-spot disease also should prove beneficial in controlling this bacterial disease. A spray of 4 pounds of zinc sulfate, 3 pounds of hydrated lime, and ½ pound of casein lime in 50 gallons of water has been reported as appreciably decreasing the spotting of leaves by this bacterium. In orchards the ill effects of the disease have been reduced by additions of nitrogenous fertilizers.

Those nurseries producing chokecherry stock should choose the seed of this species with special care in relation to its source. There is some circumstantial evidence that a disease, apparently caused by a virus and known to occur in Colorado and eastern Utah, is carried by seed. In collecting seed within the area where the disease is

known to exist, collections should be made only from areas where the plants have normal dark green leaves. Some of the leaves of the diseased plants prematurely turn a brilliant red on one side in the early fall. The following year these plants frequently fail to leaf out, or, if they do, the leaves are dwarfed, with rolled margins.

A powdery mildew on species of wild cherry occasionally causes some losses, but the disease is seldom serious. The causal fungus is *Podosphaera oxyacanthae*. Dusting with sulfur, as suggested under "Leaf Infections," will probably be more effective than spraying with Bordeaux. If, however, Bordeaux is being used regularly to control one of the leaf-spot diseases, it will probably be neither necessary nor feasible to dust. If sulfur dusting is practiced, it should not be done when the temperature is 90° F. or above because of the danger of sulfur burn. Best uniform coverage will be obtained if applications are made to dry foliage when the air is still.

Dogwood

Though dogwood in nurseries generally has been free from damping-off and root rot, it has been rather frequently observed to suffer from foliar troubles. The two of these apparently most common are a malformation and retardation of leaf development apparently caused by a leafhopper, *Graphocephala cersuta*, and a leaf spot caused by *Septoria cornicola*. Both conditions have been found occurring at the same time on 1–0 dogwood seedlings at several nurseries. At one nursery the septoria leaf-spot disease was found to have caused 50 percent or more defoliation by late June in a stand of *Cornus paniculata*, while in an immediately adjacent stand of *C. amomum* very few infected leaves were found. The *Cercospora cornicola* leaf spot, reported in the southeastern States, has not been observed to be the cause of serious defoliation in nurseries in that section of the country. Definite information as to a satisfactory control method for these leaf-spot diseases is lacking, but there has been some indication that applications of 4–6–50 Bordeaux at about 2-week intervals has materially reduced the spread of the disease.

Elm

Occasionally Siberian and American elms have been attacked rather severely by damping-off fungi. No relation was observed between soil acidity and the disease. Soil acidification appeared to be unsatisfactory as a control measure in seedbeds at an Oklahoma nursery, and where the soil was made too acid the young seedlings were severely injured or killed. Disinfection of the soil with formaldehyde some days before sowing gave satisfactory control. Losses due to damping-off were less severe on untreated beds than on soils to which heavy manure and fertilizer treatments had been applied. Early sowing at shallow depths also decreases damping-off losses. (See "Seed Problems.") Dusting the seed with 1 ounce of zinc oxide per pound of seed is the most satisfactory practical method of control for large areas but only decreases the preemergence losses. (See "Damping-off" of broadleaf species.)

A winter storage rot of the roots of Siberian elm, caused by *Chalaropsis thielavioides*, has been found on nursery stock throughout the Great Plains region and in Michigan. This rot starts in cuts and wounds on the roots and is first noticed as a white moldlike growth

that later becomes dark-colored on the injured tissues. Roots injured by termites in the nursery row are readily infected by the fungus, often decay badly, and become dark-colored by the time they are dug the following winter or spring. Seedlings with the fungus growing on the roots were planted in the spring of 1935, and only a relatively few of these failed to put out new roots or make normal growth. Examination of the plants in the lot, which after several months had made top growth, showed that the fungus had not continued to spread following planting and that the lesions were healing over. It seems probable that, where the rot has not destroyed a considerable portion of the root before planting, the plant will be able to grow if soil-moisture conditions are favorable. To prevent and control this root rot, unnecessary wounding or splitting of the roots should be avoided by careful handling of the plants, and the stock should be planted as soon as possible after lifting. It may be beneficial to root-prune the stock before growth ceases so that the resulting wounds have a chance to callus over before digging. The rot seems to spread most rapidly on the roots of seedlings in winter storage, either in cellars or when the seedlings are heeled-in, in unfrozen ground outdoors. When storage cannot be avoided, the stock will be least likely to develop root rot if stored in a cool room with just enough moisture to prevent drying out of the tops and roots. Best results to date have been obtained by heeling-in the seedlings in sand over winter in the open and protecting the tops with straw; sand that is too coarse may permit root freezing. It is not advisable to seed Siberian elm in the same soil year after year. Also, heel-in beds should be rotated.

The Dutch elm disease, which is especially serious on American elm, was introduced into the United States at several key points. This introduction was from Europe in burl elm logs imported for cutting fancy veneer. The principal center of infection is in the vicinity of New York City. The disease has been reported in localities as far west as Indiana and as far south as Virginia, but from a number of these points it has been eradicated. The disease is fully described in the United States Department of Agriculture Circular 322, Outbreaks of the Dutch Elm Disease in the Uinted States. While the disease is chiefly distributed by elm bark beetles, it may be carried for long distances in logs and living trees. Therefore, American elm seedlings grown in infected regions should be restricted in distribution to those regions. Siberian elm is highly resistant to this disease but if infected it may be a carrier. The closely related tree genus *Zelkova* is susceptible, as is also the Mississippi Valley *Planera aquatica*.

Another systemic disease with very similar symptoms of wilt and die-back is caused by *Cephalosporium*. Its occurrence on American elm is widespread and it may be distributed by infected nursery stock. Hybrid Siberian-American elm seedlings appear to be as susceptible to this disease as pure American elm. True Siberian elm is apparently very resistant or immune. A less common but very similar wilt is caused by *Verticillium*, which is considered under "Maple." Cases of discoloration in the sapwood, that are suspected of being either the Dutch elm disease or one of these similar wilts, will be identified on request if sent to Dutch Elm Disease Control, Bureau of Entomology and Plant Quarantine, Glenwood Ave. and Henry St., Bloomfield, N. J.

Disease of the mosaic type, reported on American elm in Iowa, Ohio, and the Northeast, have not been observed in nurseries. However, as a matter of precaution, the elms in the vicinity of any nursery from which many elms are to be distributed should be surveyed for diseases of this type. Early summer is the time when symptoms can be most easily recognized. Leaves remain small and are discolored, and wilting occurs. Doubtful specimens can be sent to Forest Pathology, Bureau of Plant Industry, Box 156, Bexley Station, Columbus, Ohio.

Elms, particularly American elms, are commonly subject to attack by a leaf disease caused by the fungus *Gnomonia ulmea*. In early spring, small whitish or yellowish blotches appear on the upper sides of the leaves. The spots increase in size and small black specks appear in the whitened areas. The black specks usually remain separate, but they may be so closely grouped together as to appear as a single spot to the naked eye. Later in the season the leaf tissue wears away, giving an ashen appearance to the margin of the spots. This disease may so weaken trees as to result in death by causing premature defoliation during consecutive growing seasons. While leaves are usually the only parts infected, the fungus may attack the petioles and woody tissues of young seedlings. Under nursery conditions the disease may cause much more damage to young seedlings than to older trees. On nursery stock only spraying as a control measure should start early in the growing season. It has been reported that 4–4–50 Bordeaux mixture and sulfur dusts are about equally effective.

Probably of equal importance are the leaf-spot diseases caused by *Gloeosporium inconspicuum* and *G. ulmicolum*. Control methods for these leaf spots are the same as for those caused by *Gnomonia ulmea*.

At some nurseries where red elm is grown, a leaf disease tentatively attributed to *Septogloeum* sp. is of considerable economic importance. White elm has not been found attacked by this pathogen. Limited experience indicates that applications of 4–6–50 Bordeaux mixture may help prevent losses resulting from this disease. (See "Leaf infections.")

Locust

No serious diseases of honeylocust have been reported.

In nurseries where black locust is produced there is ordinarily no serious disease difficulty, but in a few of the numerous nurseries that have grown this species in recent years, heavy losses have occurred. Seeds may fail to germinate properly because of seed coats that are impermeable to water, or they may mold in the soil as a result of injury caused by too drastic seed treatment. Pretreatment, whether by hot water, sulfuric acid, or mechanical scarification, improves permeability but should be no more severe than a preliminary test has shown is required. Some seed lots germinate readily with little or no treatment, and there are field indications that such lots are injured or made susceptible to molds and damping-off fungi by treatments which would be beneficial to seeds with less permeable seed coats. Seed that has been treated with hot water should be planted promptly. Seed subjected to sulfuric-acid treatment also preferably should be promptly planted, but if such a procedure cannot be followed the seed should be dried in order to avoid molding prior to seeding.

Germination is sometimes decreased by fungi such as *Rhizoctonia* which may also cause typical damping-off or sore-shin after seedlings appear above ground, or root rot of the plants past the damping-off stage. Soil disinfection with formaldehyde solutions applied shortly before sowing has resulted in increased emergence of seedlings. For entire safety, more than 3 days should elapse between date of application of the formaldehyde and seeding. Other disinfecting materials tested were of little or no value, and soil acidification also has given little effect.

Heat lesions, discussed in more detail under "Heat injury," have been reported on the stems of black locust.

A shriveling of the tops of the seedlings, most serious just after the seedlings appear above ground, is caused by *Phytophthora parasitica.* It is known to have caused serious loss only in three eastern nurseries; in one of these it has caused repeated failures in seedbeds during the past several seasons in a locality where there had been no previous trouble. Warm moist weather favors the sudden appearance of the disease, and seedlings are quickly killed if they are still in the cotyledon stage or have no more than 2 mature leaves. Mature seedlings in dense stands have been attacked and killed by this parasite. However, more frequently the growing tips of older seedlings may wilt when attacked, but the plants as a whole generally recover. Soil and seed disinfectants have not proved promising, while acidifying the soil to a pH of 4.6 by raking in aluminum sulfate before sowing has been followed by partial protection; such heavy acidification should not be done on a large scale until its safety has been locally tested. Frequent spraying with Bordeaux mixture, beginning immediately after the seedlings show above ground, has given very good results. A 3–4–50 Bordeaux mixture with casein or resin-soap spreader is satisfactory when applied at the rate of 6 gallons per 400 square feet of seedbed. A spreader is needed.

A root rot that affects seedlings from 3 to 7 inches high and is associated with reddish discoloration in the center of the stem has caused losses up to 10 percent of the seedlings in a large Midwestern nursery but has not been reported elsewhere, and both cause and prevention await further information. A rot of the tip of the taproot of older stock has been found in an Eastern nursery to be caused by *Phytophthora cinnamomi.* It is described in more detail under "Root infections." Under that section mention is also made of Texas root rot that has caused serious losses of black locust at nurseries located on infected soil.

One of the most conspicuous troubles in nurseries growing black locust in the South is caused by a tree-hopper insect, *Stictocephala festina.* It is described here to prevent confusion with the type of stem girdle that is discussed under "Heat Injury." This insect feeds on the seedlings and in doing so makes a ring of punctures around the stems or about the petioles of leaves of older plants. The tissue is killed in a narrow zone adjacent to the feeding injuries; this girdles the plant and frequently results in a few days in the death of the portion above the girdle. For young seedlings so injured the lower portion of the plant soon dies also. On vigorous seedlings the girdle may not be complete or may be partly healed within a short time. In such instances the plant survives and forms a swol-

len callus just above the girdle. The portion of the stem below the girdle usually remains small and weak and is easily broken in lifting and handling. When older plants with woody stems are attacked by the tree hopper, the upper portion of the stem or the leaf petioles are injured, and it is possible to find a series of swollen rings on one seedling. For further information, requests should be made to Dr. T. E. Snyder, of the Bureau of Entomology and Plant Quarantine, in care of the Southern Forest Experiment Station, Federal Office Building, New Orleans, La.

Another insect injury that may be confused with disease is that of the lesser cornstalk borer, *Elasmopalpus lignosellus*. The slender greenish caterpillars may cut off or girdle locust seedlings 6 to 18 inches in height. If the seedlings are not immediately killed, a gall-like swelling is formed on the woody stem at the point of injury, which is at the ground line in most cases. The caterpillars retreat into a web attached to the seedling below ground and may not be found when the injured plant is pulled up for examination. Further information on this insect, as for the tree hopper, may be obtained from Dr. Snyder.

Black locust appears to be quite susceptible to drought injury in the seedling stage. Dense stands of trees more than 8 inches tall exhaust soil moisture rapidly and may suffer in dry weather more than young seedlings. Wilting by day is followed by recovery during the night except in very severe cases. Drought is more likely to affect trees whose root systems have been partly killed by root-rot fungi.

Dense stands of older stock may suffer fungus leaf blight in very moist weather, the upper parts of the plants sometimes being fastened together by the rather coarse threads of *Rhizoctonia*, the only fungus thus far noted in association with this condition. Sometimes the seedling may be covered with small spherical sclerotial masses. As with drought injury, the plants along paths are least liable to attack, and thinning or thinner seeding in subsequent sowings are among the obvious measures to be used against both types of trouble. This type of disease may also be amenable to early spraying with Bordeaux, but the efficiency of spraying is low against infection that spreads from plant to plant by direct contact.

Sclerotium bataticola has been isolated from black-locust seedlings of various ages. Where the seedlings have become woody, the stems at and just above the soil level frequently are found to be filled with small black sclerotia of the fungus which are seen as black dots, especially near the cambium. Isolations from recently wilted seedlings have yielded pure cultures of the fungus. The pathogenicity of the fungus, however, has not yet been satisfactorily determined.

The brooming disease, known only in the East, needs attention when locust roots are being dug in the woods for cuttings. It is a virus disease of the peach-yellow type. Root sprouts develop witches'-broom growth either at their tips or over their whole length. The leaves on the broomed part are so small and numerous that the sprout would not ordinarily be recognized as black locust. Occasionally the brooms appear on the branches of large trees. Early-season growth may be normal, with brooming becoming most noticeable in July or August. Recovery rarely occurs, and branches that

bear brooms ordinarily die within a year so that large woody brooms are not developed. Infection is primarily in the roots, and there is no known way of recognizing infected roots unless there are sprouts from them. Areas in which any broomed sprouts are found should be avoided in taking propagating material, especially if it is to be sent to points west of the Appalachian region, and root cuttings from States in which the disease is known should be inspected after they start growth and any suspicious cuttings should be destroyed. Transmission of the disease, if it occurs, is probably rare.

Foliage of black-locust seedlings is frequently attacked by *Fusicladium robiniae* which causes a leaf spot. Generally this disease is of little importance, as most frequently it is not prevalent on the seedlings until fall. However, it has been known to attack seedlings in the cotyledon stage, in which case losses caused by this disease were severe. If young seedlings are attacked by this disease, periodic applications of a 3–4–50 Bordeaux spray are advised. Losses of black locust in storage are considered under "Molding and Decay in Storage and Transit."

Maple

The most serious maple disease is caused by a wilt due to *Verticillium*. This disease is usually most serious in regions with cool summers. Norway and sugar maples are most affected. In small trees it causes a simultaneous wilting of the entire top, with no other symptoms beyond the dark greenish discoloration found on cutting into the wood. The disease is especially likely to attack seedlings grown where potatoes, tomatoes, eggplants, or raspberries have been grown the preceding year, as they frequently harbor the same pathogen. The great damage from this disease is to plantations, and in order to safeguard them it is advisable to destroy entirely any block of stock that shows a considerable amount of infection in the nursery. In case of doubt, a pathologist should be consulted.

Wilt of soft-maple seedlings in midsummer has been found in an Illinois nursery to be due to infection at the base of the stem. A section of the stem, about an inch in length above the soil surface, is usually killed, with the pith hollow and the resultant cavity lined by very small black dots. These are the sclerotia of the fungus *Sclerotium bataticola*, which, in the absence of inoculation proof, must be considered the probable cause of the diseases. Affected seedlings are scattered rather than grouped in distribution. Since the wilting of the seedlings does not occur until the fungus has apparently been present for some time, it is doubtful whether removal of wilted plants will have much effect in decreasing loss, and spraying if successful should be done early in the growing season to prevent infection. Rotation is advisable, at least to the extent of avoiding infected beds when planting the same species the following season. Treatment of the seedbed with 1–50 formaldehyde, applied at the rate of 1 pint per square foot 2 weeks before sowing, might be tested if at any nursery the disease causes damage despite other measures to control it.

Norway maples suffer from a very distinctive but less serious trouble. Seedlings that make rapid growth in early season grow very slowly in midsummer but continue to develop new leaves of small size. The result is a rosette at the top of the stem. In late summer, normal

growth is often resumed, but the tip may die or a crooked stem may result. Insects are suspected as the cause of the abnormality, and if there is any evidence of them a State or Federal entomologist should be consulted.

Leaf-spot diseases on maples in recent years have not been reported as the cause of severe losses in Federal or State nurseries. Soft maple has been reported to be quite susceptible to injury by heat. (See "Heat and Drought Injury.") It may, therefore, be advisable, during periods of high temperature, to partially shade seedbeds in which very young soft maple is being produced. Care should be taken in shading not to interfere with the free movement of air over the seedbeds as air stagnation predisposes to top infections. A discussion of a disease that is sometimes encountered affecting maple seedlings near the base of the stem is given under "Sore-shin."

Mulberry

The Russian mulberry, *Morus alba tatarica*, grown in nurseries for shelterbelts and erosion control, has suffered in Oklahoma and elsewhere from a bacterial disease that is found on very young seedlings and also on older trees of all ages. Symptoms are similar to those reported in Europe and America as caused by *Bacterium mori*. Young seedlings first show a wilting of the leaves, that appear to be water-soaked; the infection extends down the petioles into the stem of the plant, which then wilts and dies. On larger plants, black lesions are formed on the stems and leaf petioles; these lesions may be only a fraction of an inch in length or may extend for several inches along the stem. Droplets may be seen exuding from these cankers in damp weather. Where the seedling is not killed by injury or extension of the canker, the center of the lesion sinks and cracks open, frequently exposing the pith. This disease is most serious on young seedlings and may sweep through a bed in a few days, causing heavy losses. On larger plants the damage is much less serious, as only a few small twigs are killed. This bacterial disease can be distinguished from ordinary damping-off in the seedbed by the occurrence of wilting, water-soaked leaves, and small, black stem cankers. In the first stages of damping-off, leaves appear to be healthy, while the base of the seedling near the soil line is soft and wilted. Little is known about the prevention or control of this bacterial disease. Rather limited tests with Bordeaux spray failed to control it, but soil disinfection by sprinkling the soil with a formaldehyde solution prior to seeding gave good results. When applied as a spray at weekly intervals, 0.06-percent corrosive sublimate plus 1.5-percent slaked lime or 0.2-percent potassium permanganate with 2-percent starch was reported to have controlled spread of this disease in Italy, but its effectiveness in this country has not been established. Mulberry seed should be sown in areas remote from old mulberry plantings, and badly diseased seedlings should be destroyed as promptly as practicable.

Cercospora sp. and a fungus tentatively identified as *Phleospora maculans* have been associated with several occurrences of leaf-spot diseases. Early applications of 4–4–50 Bordeaux would probably reduce spread of the diseases at nurseries where they were sufficiently prevalent to warrant treatment.

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Oak

Damage to acorns by fungi is commonly associated with weevil injury. Many of the acorns that rot in storage or after sowing are found to have been partially destroyed by weevil larvae, but in seed lots with such injury there are often a considerable number of moldy acorns in which direct injury by the weevil is limited. Weevil tunnels involving very small portions of the cotyledons seem sufficient in some cases to insure the decay of the acorns. It seems improbable that any measure directed at the fungi alone would save acorns that have been attacked by the weevils; nevertheless, seed dusting with copper or ethylmercury compounds might be worth trying if it were necessary regularly to use seed with a high percentage of weevil injury. However, past experience has shown that red-copper oxide, when applied to *Quercus rubra* acorns at the rate of 2½ percent by weight, may seriously retard germination and emergence. The possibility of controlling both the weevil and fungus by a single fumigation, as with chloropicrin, is worth considering. Preliminary trials in which acorns were stored at 38° F. resulted in reduction of additional injury from larvae and limited spread of associated molds.

A decay of the radicle (hypocotyl) of germinating white oak acorns by a fungus tentatively identified as *Rosellinia quercina* has resulted in nursery losses. Control data is lacking but small-scale tests of zinc, copper, and mercurial dusts applied to the acorns should merit trial.

A collar rot affecting seedlings toward the end of their first year's growth occurred in a Pennsylvania nursery and may appear elsewhere. It kills the seedlings in groups or patches up to 2 feet in diameter, spreading from tree to tree by a conspicuous gray mycelium on the soil and bark and attacking at the ground line. It is advisable to destroy the diseased seedlings, together with the living seedlings around the margin of the patch. More complete elimination of the disease could presumably be obtained by treating the patches with formaldehyde, at the rate of 1½ fluid ounces in 2 pints of water per square foot.

Powdery mildew appears like a white powder on leaves and soft stems and becomes so prevalent under humid conditions as to justify dusting with sulfur to prevent it. (See "Leaf Infections.") Leaf spots caused by fungi have been only infrequently reported and of those reported few have been suspected of causing serious losses.

Disease losses of oak during storage or while the stock is in transit are included under "Molding and Decay in Storage and Transit."

Plum

Wild plum (*Prunus americana*) is apparently resistant to infection by *Coccomyces lutescens* (causing shot-hole disease of cherry) but may be affected by another species of the same genus *C. prunophorae*. However, to date the occurrence of the latter fungus on nursery stock has been of little importance. The leaves, terminal growth of young seedlings, and the tips of branches of older ones have been found suffering from brown rot caused by *Sclerotinia cinerea*. The affected leaves turn brown at points of infection, and subsequently discoloration spreads until the whole leaf may be involved. Affected terminal growth of seedlings and twig tips become brown and shriveled. If moist conditions prevail, diseased parts may become overgrown with

gray moldy tufts of the fungus. Control methods in nurseries have not been developed. Experience in orchards indicates that raking and burning of all dead plant parts in the fall should decrease the infection hazard. However, it is believed that rotation and shifting of the production area from place to place within the nursery but always keeping it as far removed from any susceptible hosts in the vicinity of the nursery as possible would give better results. Spread of the disease may be held at a minimum by application of 4–4–50 or 3–4–50 Bordeaux. Root rot caused by *Rhizoctonia* occasionally results in losses.

Poplar and Willow

The leaf rusts, due to *Melampsora* spp. and characterized by orange pustules chiefly on the lower surfaces of the leaves, need attention in nurseries only if they are prevalent enough to materially weaken the planting stock. Sprays, and in some cases perhaps removal of nearby plants that can serve as alternate hosts, are preventive measures that might be employed. For the latter, specific advice should be obtained from a pathologist. The following species may serve as alternate hosts for broadleaf species: for poplars in general, these are fir, larch, and hemlock; for aspens in particular, Douglas-fir; and for the willows, the alternate hosts are larch, fir, ribes, and saxifrage.

A fungus scab and a black canker, two diseases introduced into the Northeast from other continents and extending through New York and northern Pennsylvania, occurring in the mountains of North Carolina, and recently discovered in British Columbia, are very destructive to leaves and shoots of some willow species. Nursery stock grown in the infected territory should be kept as free as possible of disease before field planting and should not be shipped into uninfected territory except under very unusual circumstances, and then only upon the advice of a pathologist.

Bark killing due to *Cytospora* and other fungi is frequent in trees growing under unfavorable conditions or in cuttings or recently transplanted stock. Plants and cuttings showing areas of killed bark when they are set out should be discarded at planting time.

Walnut

Phytophthora root rot is one of the most frequently reported, as well as one of the causes of considerable disease losses of black-walnut seedlings. Initial infection generally occurs in the roots. Usually the first apparent indication of the disease is a wilting of the more succulent portions of the tops. This is followed by the death of the attacked seedlings. Examination of such plants frequently reveals practically all of the roots to be dead and decaying, and not infrequently a dark-colored area may be found extending from the roots up the stems for an inch or more. The most practical safeguard known against such losses is to seed this species in the better drained areas of the nursery. Over-deep seeding should also be avoided. A more general discussion of this disease is given under "Root Infections." *Sclerotium rolfsii* has been reported as causing a seedling blight of black walnut in Texas.

In some instances it has appeared as though seeding of hulled nuts has given greater disease fredom than was obtained with unhulled seed. Final conclusions on this item must await additional comparisons.

In any rotation program it is wise to avoid following black walnut with rhododendron. The latter species grows poorly, if at all, on ground that has just been used to produce walnut or if grown in seedbeds that are near mature black-walnut trees, the roots of which extend into the seedbeds. Black walnut in rotation with black locust has been suspected in at least one instance of being responsible for poor growth of the locust. This, however, seems unlikely as there are a number of nurseries which have followed such a rotation schedule without any evidence of detriment to either the black walnut or black locust.

Leaf diseases are of importance at some of the nurseries. To date the leaf disease of most economic importance is one caused by a fungus tentatively identified as *Gnomonia leptostyla*. Limited nursery tests indicate that this disease is amenable to five to seven applications per season of 3–4–50 Bordeaux.

Black walnut is sometimes rather seriously attacked by the powdery mildew, *Microsphaera alni*. The methods for control of powdery mildew, described under "Leaf Infections," should prove helpful in preventing spread of this disease.

FUNGUS DISEASES OF CONIFEROUS SPECIES

KEY TO THE MORE COMMON CAUSES OF INJURY AND LOSSES

Poor emergence

Page

I. Patchy emergence followed by severe damping-off of the seedlings, especially at the margins of "fail" patches. Sprouting seed rots.
   Pre-emergence damping-off or seed decay due to damping-off fungi ---------- 49, 51

II. Patchy emergence followed by little damping-off.
   Probably drought, too deep cover, or faulty drill ---------- 10, 19

III. Poor but fairly uniform emergence not followed by an unusual amount of damping-off.
   Old, impermeable, or unripened seed; seed injured in extraction or handling; decay of less vigorous seed by weakly parasitic molds before they start to sprout; or some combination of these factors ---------- 49

IV. Emergence poorer on treated than on simultaneously sown untreated beds.
   Probable killing of dormant seed or radicles of sprouting seed by the chemicals used in treatment ---------- 71

Injury and losses of young and succulent seedlings

I. The stems of the seedlings usually become shriveled and softened, starting at the base. The seedlings soon fall over.
   A. The shriveled lower part of the stem has a dirty greenish or purplish color that shades off gradually into the normal green or red of the unaffected parts of the stem. The upper part of the seedling decays rapidly after it falls over. The root is partly decayed by the time the seedling shows noticeable symptoms above ground. Frequently diseased seedlings occur in groups of two or more.
      Post-emergence damping-off ---------- 51

II. Occurring during warm weather.

A. Needles, shoots, or whole plants die rather suddenly during or following dry weather. The condition is most common on sandy soil and in close stands, where it occurs in definite streaks or patches, sometimes as much as 2 feet in width. The seedlings along the edges of the beds usually remain healthy. Shaded beds are rarely affected. When the part of the plant above ground is entirely killed, the roots are dead also.

Drought ---------- 19

B. Disease distributed much as in A, with patches of seedlings killed in the interior of crowded beds and never, or practically never, attacking open stands or bed margins. This differs from drought injury in that it occurs when conditions have been exceptionally moist, the appearance and extension of the dead patches are a little more gradual, and some trees recently killed above ground have roots still perfectly sound.

Pestalozzia infection ---------- 64

C. Needles and upper stems of seedlings less than 4 inches high in close stands are killed under moist conditions. Affected seedlings are usually in patches up to 10 inches in diameter. No initial injury to lower stems and roots.

Rhizoctonia or fusarium, ---------- 64

D. Seedlings or transplants that yellow and die gradually are found to have dead bark entirely around the stem from the soil surface to a height of perhaps one-fourth inch. Larger stock will often have a swelling of the stem just above the dead bark before the needles begin to show signs of injury. Generally unimportant on southern species.

Heat injury ---------- 19

E. Short one-sided to girdling lesions appear on the stems just above soil. The one-sided lesions are not limited to the south side.

Sore-shin ---------- 62

F. In the spring conspicuous orange or brownish-red pustules appear on needles or break out through the bark.

Rusts ---------- 57, 59

G. Seedlings recently past the tender damping-off stage turn brown but remain standing for a time. The dead trees tend to occur in groups either in bed centers or at margins and are especially common around areas where damping-off has been prevalent. With the smaller-seeded and some of the larger-seeded pines such losses continue throughout the first season, and into the second season with spruce or where the growing season is short. Seedlings that have begun to lose color have dead root systems, and nearby green seedlings are found to have their smaller roots decayed.

Root rot due to damping-off fungi ---------- 53

H. Older seedlings and transplants die or are stunted where drought or winterkilling is not suspected, following decay of roots as in G, but more often scattered than in definite groups. Roots may or may not show resin flow.

Root rot. If trees are recently transplanted, or dying occurs at a dry time, the loss may be attributable to a combination of partial root rot with either transplanting injury or drought ---------- 16, 19, 53

Seed Decay

Coniferous seed if moist is sometimes badly molded in the partly opened cones, or after extraction while in storage or transit. The appearance of fungus growth on seed does not always mean injury; the first visible development of the fungi is often superficial or on broken and imperfect seed. Reasonably good germination was obtained from jack-pine seed that had been shipped in a tight drum and was conspicuously overgrown with blue-green mold (*Penicillium* sp.). Loss from decay in storage apparently is least frequent for most pine species when the seed is stored with a moisture content of about 6 to 8 percent at 32° to 38° F.

Seed may be destroyed in the soil before sprouting begins. Damping-off fungi have been shown to be capable of attacking unsprouted seed. There have been frequent cases of poor emergence, however, in which no biological cause could be detected and in which there was little post-emergence loss, indicating that damping-off organisms were not active; for such cases one of the more probable explanations is

decay by organisms that are unable to attack actively growing tissue. Such cases of loss have been noted most often in cold, wet weather. *Rhizopus* and *Fusaria* are among the organisms suspected of being associated with such losses, and bacteria may also prove important. Organisms that may cause decay after the seed is sown are sometimes found inside the seed coats of apparently sound, stored seed. Decay of seed by damping-off organisms is greatly reduced by the soil-treatment methods that will be described for preventing damping-off, but cold-weather germination failures have frequently occurred in beds that had been given efficient damping-off control treatments. The liability of seed to decay in the soil will presumably be decreased by proper extraction and storage methods and by using the seed before it begins to lose its germinative vigor as a result of age. Treatments which hasten germination should reduce losses unless so severe as to injure some of the seed, in which case they are likely to favor fungus attack. The use of dusts to reduce the storage-decay hazard is discussed under "Seed Treatment."

Fungi sometimes spread rapidly through stratified seed. Losses from this source seldom have been reported and have not been intensively studied.

Damping-off

Damping-off is a general term used for the killing of very young seedlings by fungi. It is the most widespread and probably the most important forest-nursery disease in the United States. In most localities pine, spruce, fir, hemlock, and larch regularly suffer more or less from damping-off, with occasional severe epidemics in which certain species are nearly wiped out. Among the pines, those with large seed are with a few exceptions generally less affected than the smaller-seeded species. With the cedar relatives, *Juniperus*, *Cupressus*, *Chamaecyparis*, and *Thuja*, damping-off is ordinarily negligible, but there have been some reports of losses with *Cedrus*. Pre-emergence damage cannot be seen and the younger seedlings that damp off soon after emergence usually decay and disappear so quickly that only a few of them are to be seen at any one time; losses due to damping off, therefore, are usually underestimated. Besides the aggregate loss, serious for a crop in which seed is so expensive, the uncertainty which damping-off epidemics introduce into seedling production is a decided nuisance. The extent to which the disease increases the uncertainty in yields is best indicated by greater stand-density variation in untreated beds than in beds which receive fairly efficient control treatments. Increased variation in yield due to damping-off makes it difficult for the forest nurseryman to gauge his sowing operations to the needs of the field planting program. Damping-off also hampers control of stand density and thus of quality of stock.

The damping-off hazard can be greatly lessened by choosing acid nursery sites, by avoiding the use of lime, ashes, alkaline water, and alkaline cover sand, and in most nurseries by fall or early-spring sowing and by postponing applications of nitrogenous materials until after the damping-off age has passed. Extreme shading and stoppage of air movement should be avoided, but the manipulation of shades and control of watering to which freedom from disease is ascribed by many nurserymen are far from being panaceas. It is

impossible or impracticable on many sites to keep damping-off within reasonable limits without soil treatments. The soil treatments that have been developed all have limitations. They rarely give complete control and are not advised for nurseries where loss is slight; but at nurseries where there is much loss they often make the difference between success and failure, and in many places pay for themselves by weed control. A detailed discussion of amounts and the technique of application of various seedbed treatments is given under "Control Measures."

Damping-off losses of the soil-infection type are considered under three headings: (1) Pre-emergence Damping-off, (2) Post-emergence of tree seedlings. Fortunately the pre-emergence form of the disease is the easiest type to control.

Pre-emergence Damping-off:

The killing of unsprouted seed in seedbeds by damping-off fungi has been mentioned under "Seed Decay." Seedlings that have not broken through the soil can be killed in large numbers by either *Pythium ultimum* or *Rhizoctonia solani* and probably to a less extent by *Sclerotium bataticola*, *Fusarium*, and other fungi. When infection of the soil is heavy, emergence in untreated beds is sometimes as low as one-third of that obtained in beds that have received an efficient protective treatment. Beds with much pre-emergence loss due to damping-off fungi commonly show rather heavy loss after emergence. Pre-emergence damping-off is, therefore, to be suspected as the cause for emergence failures in beds where there is a good deal of the visible type of damping-off. *Rhizoctonia* in particular sometimes causes failure of emergence on areas several inches in diameter. The responsibility of this fungus for such "fail spots" is immediately made evident after emergence by the heavy damping-off loss that is observed in the seedlings around the edge of the spot. Large fail spots due to this fungus may be clear of weeds as well as of tree seedlings. Fortunately the pre-emergence form of the disease is the easiest type to control.

Post-emergence Damping-off:

The usual type of post-emergence or ordinary damping-off is due to infection at or more often below the soil surface; it may occur at any time after the seedlings start emerging and may continue as long as the stems remain succulent. The root or hypocotyl is rotted, and the seedling falls, usually with a sharp bend at or just above the soil surface. Infections that start some distance below the soil surface usually are not evident until the decay of the stem has extended to a point above the soil surface. *Pythium* and *Rhizoctonia* are probably the principal offenders, but there is need for further study of the effects of *Phytophthora cactorum* at low temperatures, *Fusarium* spp. at high temperatures, *Cylindrocladium* on acid soils, and some other organisms that are found in association with the disease. *Rhizoctonia* is usually responsible for fewer but larger groups of dead seedlings than is *Pythium*.

"Damping-off" is really a poor name for this ordinary soil-infection type of the disease; the losses show no distinct correlation with the ordinary variation in field moisture conditions, though beds completely enclosed in cloth or burlap ultimately become very susceptible. Whatever it may be possible to do under the controlled moisture

conditions that can be maintained in greenhouse or laboratory, it does not appear to be practicable to control soil moisture enough in the nursery to materially decrease ordinary damping-off. Moderately high temperature seems to favor damping-off; seedlings have been found to show first symptoms particularly on days when the soil was dry. Heat injury, especially of succulent seedlings, is sometimes mistaken for damping-off.

Some organic matter in the soil seems to be required by *Pythium*, but *Rhizoctonia* spreads readily through nearly pure sand. Poorly rotted manure and all fertilizers rich in nitrogen increase the liability to damping-off. Phosphates on the other hand sometimes seem to decrease the hazard. Green manures, particularly leguminous, turned under shortly before seed sowing may be expected to cause an increase in damping-off; however, there is little evidence on the subject. In general, the more acid the soil the smaller the losses, though epidemics occasionally occur on soils with pH values as low as 5.0 or less, in which cases excessive nitrogen addition or the fungus *Cylindrocladium* may be found. Some reports of damping-off on acid soil have been found to be instances of top-damping-off. On soils containing enough carbonates to effervesce on the addition of acid there are almost certain to be heavy losses, and the addition of wood ashes, ordinary lime, or alkaline sand in a pine or spruce nursery is an invitation to trouble. The effect of dolomitic lime, and of other calcium compounds, as the sulfate, which do not raise pH, should be studied further. Different seed lots of Douglas-fir and ponderosa pine vary in damping-off susceptibility, but source of seed is commonly dictated by requirements of field-planting sites, and susceptible host strains must sometimes be used.

In southern nurseries damping-off of longleaf pine is a common occurrence and differs in some ways from that of other pine species. The accumulation of sand or soil from erosion or any other cause in the crown of the seedlings aggravates the disease even on acid sites. While it is thought that suffocation and lethal temperatures induced by the accumulated soil may be contributory factors to these losses, it is apparent from experimental work that damping-off fungi are mainly responsible for these losses.

Diplodia (*Sphaeropsis*) *pini* may cause damage to seedlings of certain coniferous species such as Austrian, ponderosa, and nut pines and Douglas-fir, especially when the soil is water-logged from heavy rain. Better seedbed drainage and soil aeration should reduce the hazard.

Late Damping-off:

Late damping-off is considered to be an early stage of root rot and will be discussed under "Root Rot."

Top Damping-off:

Infection of tops of seedlings may occur as a result of overshading and smothering by mulch or burlap left too long over the germinating seedlings, or of continued extreme moisture from any other cause. Of the fungi that ordinarily cause root infections, *Rhizoctonia* and *Fusarium* may also attack the seedlings above ground. Initial cotyledon infections that develop simultaneously throughout the seedbeds usually occur while the seed coats are still adhering, and in many

cases probably started before the seedlings emerged. Infection also occurs sometimes at the base of the cotyledon whorl, probably starting in the drops of water that often persist at that point for some hours after rain or sprinkling. The epidemics of phytophthora top infection in spruce seedbeds reported in Europe half a century ago are unknown in the United States, but red spruce has suffered in a young stage from top infections with which *Rhizoctonia* and *Fusarium* were associated. In general, top infection of conifers young enough to exhibit typical damping-off symptoms has been rare. Such infection, unlike the ordinary soil infection type, is dependent on abundant moisture and really deserves the name "damping-off."

Root Rot

Caused by Damping-off Fungi:

In beds of seedlings that have just developed stiff stems, the damping-off fungi may continue to cause losses for 2 or 3 weeks, and sometimes to the end of the first season or with some species into the second season. However, the more usual effect of these or related fungi is the killing of the youngest parts of the roots, which are replaced by new roots. The new roots grow out of the main root just above the upper end of the killed portion; the higher lateral roots are often stimulated into an unusual amount of growth. The attack may be limited to the deepest part of the taproot, and possibly even have some of the beneficial effect of root-pruning; or it may so reduce the root system as to cause serious stunting. Usually the effect is intermediate between these extremes. Failure of young trees to establish themselves in plantations may be due in part to spread of fungi already established in the roots before digging or to the invasion of fungi from the soil in the new location. The numerous root wounds made in digging undoubtedly favor infection. As with damping-off, it is to be expected that dense stands, high pH, poor drainage, and excess nitrogen will favor root rot both of trees just transplanted and of those already established. Heavy loss has been observed in several nurseries in transplant beds to which considerable manure had been added.

Root rot is sometimes appreciably decreased by the damping-off control treatments applied at or before sowing, but rarely to a satisfactory degree unless so much of the chemical is used as to be dangerous to the sprouting seed. Aluminum or ferrous sulfate, as applied 3 weeks after emergence in the amounts used against damping-off or one-fourth larger, dissolved in at least 1 pint of water per square foot of seed bed, has been used with advantage in some cases. For more details see "Seedbed Treatments for Damping-off Control."

Caused by Phytophthora:

Pinus resinosa, *P. sylvestris*, *Picea pungens*, *P. abies*, *Pseudotsuga taxifolia*, *Taxus* (Japanese, English, and varieties), and *Larix* (Japanese and European), as well as a number of broadleaf species, are known to be susceptible to a root rot caused by *Phytophthora cinnamomi*. Losses due to this fungus are known to occur only in the Middle Atlantic, Southeastern, and south Central States, and in only a few of the nurseries in these States. Infected trees are usually killed. The first indication of trouble is the gradual loss of the natural green color of the needles. Obvious wilting occurs only when

very young shoots are present. This root rot, in common with some other root diseases affecting conifers, causes an external resin flow. It also has the more distinctive characteristic of causing resin infiltration of the wood underlying the earliest-infected bark. The disease is most severe on poorly drained soil. No relationship to soil pH has been noted. Before shipment of stock the soil should be thoroughly removed from the roots of all species from nurseries where this disease is most severe on poorly drained soil. No relationship to soil pH has to raise the susceptible species in areas, especially poorly drained ones, where the disease is known to have occurred.

Caused by Other Fungi:

Root rot caused by the fungus *Rhizina inflata* has occurred in pine and spruce seedbeds. Seedlings beyond the damping-off age yellowed and died gradually. The fruiting bodies of the fungus, deep brown with narrow white margins, occurred on the surface of the soil near the base of the affected stock. The losses were limited to localized areas where brush was said to have been burned.

Three well-known root rots of forest conifers are caused by *Fomes annosus*, *Polyporus schweinitzii*, and *Armillaria mellea*. *F. annosus* has been observed killing redcedar about 3 years old in natural reproduction but it has not been seen in nurseries. *P. schweinitzii* can attack pine seedlings only 1 or 2 years old, but it has not been found in nurseries. On a few pines in a nursery on a recently cleared site the characteristic "shoe strings" of *A. mellea* were found associated with killing lesions and probably were dependent on the presence in the soil of decaying roots of the large trees originally on this area. It is not likely that any of these will ever cause important losses in established nurseries. All, however, deserve some further attention because even a small amount of infected stock might introduce the disease into plantations, particularly if used for filling in gaps in older plantations. *Armillaria* is the easiest of the three to detect and in one nursery its presence resulted in regulatory restriction on shipment of stock by State authorities.

Rather serious root-rot losses of red spruce have occurred in 2–0 seedbeds and in transplant areas. The disease in seedbeds may occur on well-drained soil and the most frequently associated fungus has been *Sclerotium bataticola*. The transplant losses have been most severe in the more poorly drained areas but they may occur to some extent on fairly well-drained soil. The causal agent has not been determined but there is strong evidence that the disease is transmissible (fig. 7). Root-rot losses of a parasitic nature have occurred in 1–0 slash-pine seedbeds. The disease attacking the transplanted stock appears to be spread by practices that result in movement of small quantities of soil from one area to another by cultivation or through the use of infected cull stock as an organic soil amendment in disease-free sections of the nursery. Concomitantly the hazard of spreading the disease may be reduced by avoiding these practices.

The fungus *Phymatotrichum omnivorum*, which causes the Texas root rot of cotton and attacks a great variety of broadleaf plants, in addition occurs on conifers in alkaline soils in the Southwest. Though never reported on conifers in forest nurseries, nursery stock should not be grown on soil in which the fungus is known to occur.

The pseudomycorrhizal fungi in some cases are suspected of having a harmful effect but there is no definite evidence on the subject. This is discussed under "Mycorrhizae."

Rusts

Pine Gall Rusts:

Native rust-induced galls are widely distributed on two- and three-needle pines. Some nurserymen use the word "rust" for any disease that produces reddish or brownish colorations. However, the general practice established by half a century of usage by technical men in both Europe and America is to consider as rusts only a particular group of fungi (the Uredineae) that develop in living

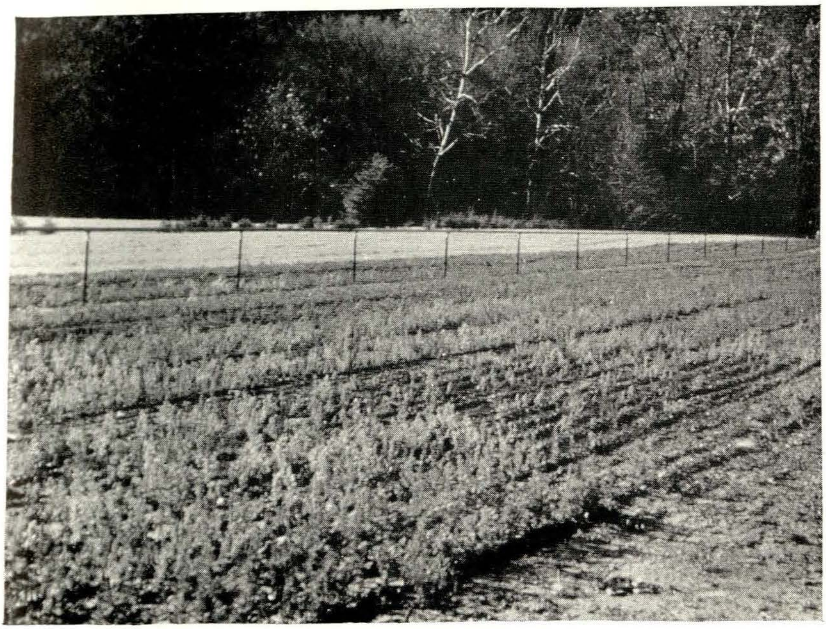

FIGURE 7.—Root-rot losses and injury in transplanted red spruce. The light-colored seedlings are chlorotic and many of them probably will die as a result of the root infection.

leaves, stems, or branches without immediately killing them and produce characteristic pustules of rust-colored spores. Some of them stimulate the host to develop galls or witches'-brooms. There are two which must go to oak for their alternate spore stage: *Cronartium cerebrum*, which produces ball-shaped galls in the East, and *C. fusiforme*, which gives rise to spindle-shaped swellings and is found only in southern States. In early spring spores that are capable of infecting the leaves of oak and related genera are produced on the mature galls. A different type of spore that is capable of infecting the pines is produced by these fungi on young leaves of oak and related genera. The hard pines in general can be attacked. Species of the black-oak group are susceptible, while the white oaks are

infrequently infected. Cronartium rusts are not known to spread from pine to pine.

Peridermium harknessii, another gall rust of the two- and three-needle pines, causes galls similar to those of *C. cerebrum* and occurs in the West. This rust does not require an alternate host as it spreads readily from pine to pine, though some strains of it or of a similar western gall rust appear to be able to use as alternate hosts the Indian paintbrush, *Castilleja* spp., and perhaps require it. The so-called Woodgate rust, known in New York and said to occur in Michigan, New Jersey, and Canada, also goes from pine to pine and may be *P. harknessii* introduced from the West.

In the South infected first-year seedlings commonly show evidence of rust by fall. Where visible swellings are produced they may easily escape detection or be confused with mechanical-injury swellings or

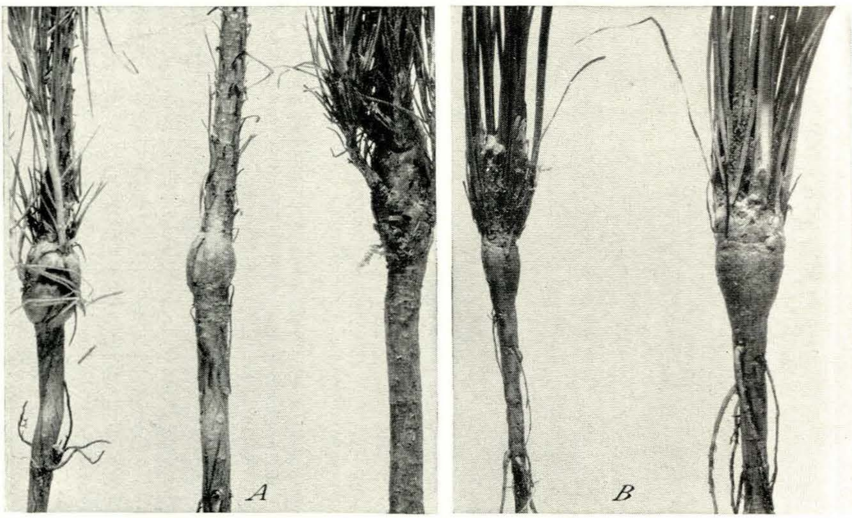

FIGURE 8.—(*A*) 1–0 slash pine and (*B*) longleaf pine seedlings showing stem swellings (galls), resulting from infection by rust fungi.

the swellings that are normally present at the cotyledon whorl in some species. *Peridermium harknesii* has never been detected in important amounts in nurseries, but has been shown experimentally to infect seedlings. *Cronartium cerebrum* has been found on Austrian, jack, and shortleaf pines in nurseries. *C. fusiforme* has recently been found causing perceptible swellings on as much as 15–20 percent of 1–0 slash and loblolly pines in some of the southern nurseries. (Fig. 8.) These diseases are not known to kill any trees in the nursery. However, nursery-infected stock survives only a few years after being planted in the field. Not only do the infected trees die, leaving gaps in the plantations, but they also serve as the indirect source of inoculum for the infection of the other trees in plantations mixed with oak.

The damage from these rusts in plantations may be reduced by discarding at time of lifting any trees of susceptible species which have unusual or suspicious swellings (not due to insects) on the stems. Doubtful cases can be submitted to a pathologist for micro-

scopic verification. In large-scale operations culling out diseased specimens can never be done thoroughly enough to get out all of the infections; therefore, stock from an infected nursery should not be shipped into rust-free regions unless these are also free from alternate hosts. Bordeaux (8–8–100) spray may effectively reduce the amount of seedling infection by *C. fusiforme* if frequent applications are made during the periods of greatest infection hazard (fig. 9). Santomerse S, used at the rate of 1 pint per 100 gallons, has proved to be an effective spreader; three-fourths pint per 100 gallons may prove more satisfactory in power sprayers that have

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FIGURE 9.—Protecting longleaf-pine seedlings from rust and brown spot by applying Bordeaux mixture with a power sprayer. (U. S. Forest Service Photograph.)

comparatively large agitators. The removal of oak, in order to be effective against this fungus, may have to be extended to such a distance as to be impracticable. To minimize hazard from *Peridermium harknessii*, the best practice is to prune out the rust galls on all infected pine for at least one-fourth mile from the nursery.

Pine Rusts Which Do Not Produce Galls:

The introduced white-pine blister rust, *Cronartium ribicola*, which attacks the five-needled pines, has currants and gooseberries as necessary alternate hosts. In the parts of the country where this rust is known to occur the Bureau of Entomology and Plant Quarantine conducts a systematic campaign for its control, a part of which involves the removal of the alternate hosts in the neighborhood of nurseries that grow white-pine species. Information concerning approved practices and cooperative service is best obtained by applying directly to that Bureau, or to the State Nursery Inspector or State Forester.

The native blister rusts of the two- and three-needle pines include:

Cronartium filamentosum in the West with alternate stage on Indian paintbrush (*Castilleja* spp.) and *Orthocarpus*.

C. Comptoniae in the East and Canada, to which *Pinus ponderosa*, when introduced into the East, is extremely susceptible, and which has for its alternate hosts species of *Comptonia* and *Myrica*.

C. pyriforme in both the East and West with alternate stage on bastard toadflax (*Commandra pallida*).

C. occidentale occurs on the piñon pines and is important chiefly because of the tendency to confuse its alternate stages on ribes with those of the white-pine blister rust.

Only *Cronartium filamentosum* and *C. comptoniae* have been observed infecting nursery stock to an appreciable extent, but all of those named can cause infection, which it may or may not be possible to detect by close examination of the nursery, since the swellings produced are slight and spore production may not occur until some years after infection. The removal of the alternate hosts from the neighborhood of the nursery is probably the most successful method of protection against all these blister rusts. This is not always a practicable or necessary procedure. Two European hard pine rusts, *Peridermium pini* and *Melampsora pinitorqua*, the latter attacking very young seedlings and causing them to twist, are not yet known to occur in this country.

Cedar Rusts:

Redcedar is the alternate host of apple rust, *Gymnosporangium juniperi-virginianae*, and of the quince and apple rust, *G. clavipes*. Consequently regulatory redcedar eradication laws have been passed in some fruit-growing States.

The cedar rusts do not ordinarily appear in nurseries, but redcedar and other junipers are less likely to be infected if they come from nurseries where apples, quinces, or hawthorns do not occur in the immediate neighborhood. For *Juniperus ashei*, precautions appear to be unnecessary. These rusts can be controlled by sprays, but it is somewhat difficult to keep either host protected during the time that infection may occur.

Spruce Needle Rusts:

The needle rust fungi, *Chrysomyxa cassandrae*, *C. ledi* (*abietina*) and *C. ledicola*, named in order of apparently greatest frequency of occurrence in native growth, are difficult to distinguish from one another in the aecial stage. The alternate hosts for these fungi are members of the heath family; principal among them are leatherleaf, Labrador tea, and bog rosemary. There is no evidence that the rusts will spread from spruce to spruce. Plantation and native forest observations indicate relative susceptibility of several spruce species to be: Susceptible, *Picea mariana* and *P. pungens;* moderately susceptible, *P. glauca;* resistant, *P. glauca* var. *albertiana* and *P. abies*. The occurrence of these rusts in epidemic form is not frequent. Even in epidemic form no serious results are to be anticipated in the way of permanent deformity of infected trees, though they are undoubtedly weakened. Control methods lie in the eradication of the alternate host, a rather impracticable procedure in most regions, and in spraying the spruce during the infection period. The latter practice is also probably inadvisable as the disease ordinarily causes little injury

to the host and does not occur in epidemic form every year. However, for stock of special value, in nurseries where the rust has been known to occur, a 4–4–50 Bordeaux spray may be justifiable as an insurance measure. It should be applied at about the time the current year's needles are reaching full length and before they have started to harden.

Pucciniastrum arcticum on white spruce and *Peridermium coloradense* on North American spruces, the latter fungus causing witches'-brooms, have not been reported in nurseries.

Pine Needle Rusts:

Pine needle rusts (*Coleosporium spp.*) are characterized by the occurrence of yellow- to orange-colored pustules on the needles. (Fig. 10.) Needle rusts generally cause little if any trouble in nurseries.

FIGURE 10.—Needle rusts on pines: *A*, *Coleosporium solidaginis* on shortleaf pine, *B*, *C. carneum* on loblolly pine. (Photograph of G. C. Hedgcock.)

In places where they are often so abundant as to reduce greatly the effective leaf surface, infected composites and morning-glories in the near vicinity should be mowed or otherwise eliminated about July and again at a later date if they make much subsequent growth. For the needle rusts that lack an alternate stage it would be necessary to cut out nearby infected pine. The advice of a pathologist should be secured before proceeding with either of these control practices.

Hemlock Needle and Tip Rust:

On hemlock a rust caused by *Melampsora farlowii* is known sometimes to attack needles and new shoots, causing them to die and curl, and occasionally is severe enough to cause serious damage in nurseries. Lime-sulfur (4 pounds of the dry form to 50 gallons of water) applied weekly through May, in the Appalachian section of North Carolina, has been reported as an effective control. A good spreader, preferably casein or raw linseed oil, is essential because of the waxy character of the young growth. Removal of infected neighboring trees is advisable.

Spruce Tip Killing

Killing of the terminal and lateral buds of red spruce has caused considerable damage in at least one nursery. The disease occurred on both 1–0 and 2–0 seedlings and apparently was caused by *Rhizoctonia*. It was most severe in dense stands of 2–0 seedlings where the fungus seemed to have little difficulty in spreading from one plant to another by direct growth of the mycelium. Cloudy weather with frequent showers and a high relative humidity seemed to favor the disease.

One of the most conspicuous symptoms of the disease was the bending of the infected stem tips, usually at a 95° angle, although often at only a 15° to 20° angle. Spraying with Semesan, according to the manufacturer's recommendations, or 4–4–50 Bordeaux, if done early enough, should prove to be beneficial in checking the spread of this disease, although removal of shade frames, thinning the stand, or any other practice that will reduce moisture around the seedling may prove to be more beneficial.

Cedar Blight

"Cedar blight" or "juniper blight" is widespread as a nursery disease in this country, probably being present at one season or another wherever redcedar (*Juniperus virginiana*) is regularly produced. It is due to the invasion of leaves and small stems by the fungus *Phomopsis juniperovora*. Seedling and transplant beds alike are subjected to attack by the disease throughout the growing season.

In advanced stages the blight may be characterized by the occurrence, in groups or as scattered individuals, of dead seedlings or seedlings on which only the terminals or spurs have died. Small dark pycnidia appear on the stem and needles of the infected trees. On the older portions of the stems may be found longitudinal lesions that develop into definite sunken cankers.

The spread of the disease appears to be favored by conditions associated with rapid growth of the seedlings. Of these factors, rainy periods appear to be most significant in relation to the occurrence of severe loss, and soil fertilization with ammonium sulfate has been observed to increase the losses. It is under moist or humid conditions that the *Phomopsis* spores are readily disseminated and infection is enhanced.

Greek juniper, *Juniperus excelsa stricta*, *Juniperus virginiana* var. *keteleeri*, and "Dundee" juniper, *Juniperus virginiana* var. *pyramidiformis* f. *hillii* have been reported resistant to blight. It is possible that seed collected in some localities or from certain trees may prove to be more resistant to the blight than seed from other sources.

So far as is known, Bordeaux mixture (4–4–50), colloidal sulfur, and normal Semesan applied as sprays, give the best promise for controlling the blight when used in coordination with sanitation measures, but have not been as successful as might be desired. At nurseries where juniper hedges are used as windbreaks it would be advisable to spray them also. It is essential that the first application of spray material be made in the spring before infection occurs and that the foliage be thoroughly covered at each application of the spray. Spreaders are particularly needed; these are discussed under "Spraying." Frequency of spraying depends on weather conditions and the degree of the local hazard from the disease. During seasons

of abundant moisture, it is important to spray consistently throughout the growing season, beginning early so that the new growth is constantly covered with a protective coating. Less frequent spraying might be consistent with weather with little rain, sprays being applied 2 to 3 weeks apart, and in wet seasons at more frequent intervals. Root pruning is reported to have some value as a control measure.

Sanitation also should be practiced. Diseased trees or parts thereof should be cut out and burned as soon as observed. The sanitary precautions should be co-ordinated with the spray treatments. The use of cedar boughs and needles for mulching beds sown to this species should be avoided.

Needle Spots

Brown spot, caused by *Scirrhia acicola*, is a juvenile needle disease of southern pine; it usually makes its first annual appearance in nurseries in early June. It is identified by the occurrence of small but conspicuous spots that frequently start about midway between the base and tip of the individual needles. These spots soon encircle the needle as brown bands. Longleaf pine (*Pinus palustris*) is the most susceptible, loblolly pine (*Pinus taeda*) is relatively resistant, and slash pine (*Pinus caribaea*) is moderately resistant, while the hybrid sonderegger pine (*X Pinus sondereggeri*) is of intermediate susceptibility to this disease. The more severe occurrences of brown spot on longleaf pine result in nearly complete defoliation. Badly infected stock is weakened, and infected stock should not be sent into an area where this infection does not occur. In North and South Carolina this disease is seldom serious on 1-year-old stock but often is the cause of defoliation of 2-year-old stock. In nurseries in the Gulf States it is a serious problem on 1-year-old as well as older nursery stock.

Reasonable control of the disease in nurseries, providing it is started before the disease makes much headway, may be secured by spraying with homemade Bordeaux (4–4–50) containing 2 pounds of whale-oil soap in 50 gallons of mixture. The spray functions as a preventive and not as a cure; hence, the first application of the spray should be made in late May or early June. The frequency and time of subsequent spraying depend on local conditions. In regions where longleaf pine is known to suffer rather heavy annual infection with brown spot, four sprayings may be required. Sprayings may be essential even in the late fall as the disease can be readily carried from the nursery to the plantation. For 2–0 longleaf-pine stock that has not been sprayed sufficiently to prevent severe infection, it may be advisable to burn the beds some time prior to lifting. To avoid heat injury to the trees the burning should be done in the morning when the dew is gone, following a cool night (near freezing). A steady wind velocity of 6 to 8 miles an hour is desirable. A fire torch and back-pack fire pump are useful; the fire torch serves to singe off the infected needles, while the back-pack fire pump is used to extinguish the fire as soon as the infected needles have been destroyed. Fire has not been successfully used on any species other than longleaf pine.

Red spot is a disease very similar to brown spot. The fungi causing the two diseases are also similar, the one causing brown spot having amber-colored spores, whereas those of the pathogen responsible for red spot are hyaline. Red spot is known to occur on Austrian, maritime, and other hard pines, chiefly in Ohio. Control measures, with the exception of burning, are the same as those given for brown spot.

Mistletoe

The dwarf mistletoes of the genus *Arceuthobium* are potentially very harmful to ponderosa pine, Douglas-fir, and other coniferous species in the drier parts of the West. At nurseries producing susceptible species and where infected trees border the seedbed area, these mistletoes are capable of infecting the stock. Natural infections in nurseries have probably occurred but have not been observed because they would not be immediately visible. By cutting out infected trees or branches to a distance of several hundred feet from the seedbeds, the amount of nursery infection should be negligible.

Sore-shin

This disease, unobserved on pine nursery stock less than one year old, is characterized by the occurrence of apparently fungus-induced lesions on one side of the stem. These lesions resemble those caused by heat injury but differ from them in not being predominantly on the south or southwest side of the stems. A further distinction is their occasional occurrence on the stem just beneath the soil surface as well as at and up to 1½ inches above it. There is some evidence that the causal organism enters through mechanical injuries, and in the case of the lesions higher up on the stems, entrance may be at the base of the needles. No remedy for this disease is known. At nurseries suffering serious loss from this disease, it may be profitable to undertake small-scale tests spraying Bordeaux mixture onto the base of the stems.

Thelephora

The dull-colored sporophores of these fungi may be found growing around the stems of both spruce and pine seedlings of all ages, occasionally climbing so high as to partly cover the needles of the smallest seedlings and smother them. Heavy growths of the fungus are occasionally associated with the yellowing of pine where there is no obvious smothering. Investigators are generally agreed that the fungus hyphae do not penetrate the tissues of the seedlings; any actual harm to the seedling is ordinarily slight and perhaps the result of effects on organic matter or microflora in the soil. Nevertheless the yellowing, if present, and the sporophores, which are difficult to remove from the tree, sometimes decrease its merchantability.

When it is desired to free the stock from the fungus, Bordeaux or lime-sulfur spray may be helpful. A 4–6–50 Bordeaux has given favorable results at one nursery. The destruction of affected stock is not advised as a method of control. In some cases transplanting the stock and holding it for an additional year in the nursery will result in its outgrowing any ill effects caused by *Thelephora*.

Mold Under Snow

The best-known fungus injury connected with snow cover in nurseries is that caused by *Phacidium*. This disease is most troublesome in the northeastern part of the United States and is limited to regions where the stock is snow-covered a large part of the winter. Terminals or other parts of the plant tall enough to be exposed above the snow are not affected. Spruces and balsam fir are susceptible; some pines may be attacked.

Primary infection appears to occur in the fall and winter while spread by contagion occurs in the spring. In either event, the full extent of damage is not readily apparent until after the melting of the snow cover in the spring. The affected current season's needles are early dotted with micro-sclerotia. The needles are glaucous brown, and by fall, dark disklike apothecia appear on their under side. In broadcast-sown beds the affected stock is in patches radiating out from a common point of initial infection, while in drill-sown beds the diseased condition is found for the most part to follow along the drills. The fungus is readily carried to plantations from the nursery on infected stock.

In nurseries satisfactory control has been obtained by using dormant strength lime-sulfur. The lime-sulfur spray should be applied as soon as the trees become dormant in the fall. Spring sprayings have proved to be ineffective.

Douglas-fir in a high-altitude nursery, which for approximately 6 months each year was so heavily snow-covered that the ground remained unfrozen, annually suffered from top infection by *Botrytis cinerea*. Thin stands were affected more than dense stands, probably because isolated seedlings were more completely forced against the mud. Lime-sulfur spray in the fall was helpful; Bordeaux mixture caused injury to the seedlings.

Other Needle and Stem Diseases

The group of needle diseases usually referred to as needle casts, caused by species of *Hypoderma* and *Lophodermium*, attack a number of American conifers. However, they are best known from studies that have been made on them in Europe where the so-called Schütte caused by *Lophodermium pinastri* in Scotch-pine nurseries has drawn much attention. It is known to cause serious losses of 1- to 3-year-old red, jack, and pitch pines in New England. The needles become light green or grayish-green in late fall, and in the spring they show dead spots and die-back; they then die and fall prematurely, weakening and killing some of the stock. At some of the nurseries in the northeastern United States, *L. pinastri* has been sufficiently prevalent on red pine to require spraying. Spraying with double strength (8–8–50) Bordeaux, when the needles are half-grown, and repeating at intervals of 3 to 4 weeks until growth ceases, has been recommended. Also, it is advisable to eradicate all infected pines within 100 yards and other pine trees that repeatedly show heavy infection within 300 yards of the nursery beds.

Another needle disease of some importance, that has been reported in an American nursery, is caused by *Rhabdocline pseudotsugae*, a native of the northwestern United States, though best known for its activities when introduced in Europe. In a Montana nursery bordering an

infected native stand of Douglas-fir, seedlings of this species were infected sufficiently to make spraying advisable. This fungus is not known to attack other tree species. Fungi that ordinarily attack older forest trees are not likely to cause trouble in nurseries unless the nurseries are located near naturally infected stands of the susceptible species, or mulched with material of the same species.

Under unsusally moist conditions some nonspecialized fungi of the type that cause damping-off (*Rhizoctonia* and *Fusarium*) can also attack the needles and stems of trees of various ages in both seedbeds and transplant beds. Grey mold, caused by *Botrytis cinerea*, has been known to occur on Douglas-fir and redwood seedlings. *Rhizoctonia* and *Fusarium* have been known to attack the tops of pine seedlings. The two last-named fungi may affect the seedlings in patches 8 to 10 inches in diameter, spreading through the crowns and killing them without any immediate damage to the lower stems or the roots. *Pestalozzia funerea* is known to invade the soft stem tissues of 2-0 pine, producing lesions that may girdle the stem; the top of a girdled plant may live for some time, and may even make a slightly swollen growth above the girdle in the way that sometimes occurs with certain mechanical or heat lesions. Top infections with these nonspecialized fungi are usually limited to very dense stands and moist weather. In addition to these predisposing conditions, poor circulation of air because of high side boards, heavy shade, or any tight covers that are sometimes used will increase the disease hazard. In pine stands dense enough to result in damage of this sort, it is difficult, if not impossible, to stop the spread of the fungus by spraying. Thinning, shade removal, or some other method of giving the tops a chance to dry out would be a rational control measure. The tops and stems of 2-0 white pine have been observed seriously attacked by *Cylindrocladium*. There is some indication that such infections may be reduced by periodic and thorough spraying of stems and needle bases with 4-4-50 Bordeaux or normal Semesan. Under some conditions there is danger of the latter spray material causing injury.

Crown gall caused by *Pseudomonas tumefaciens* has been reported on *Juniperus* spp., *Cupressus* spp., *Sequoidendron giganteum*, *Araucaria bidwillii*, and *Libocedrus decurrens* but is not believed to be of any economic importance in coniferous forest nurseries.

CONTROL MEASURES

Seedbed Treatments for Damping-Off Control

At nurseries where there have been plenty of field trials of treatments in the past, the specific local experience will, of course, be the best guide as to further procedure. The folowing advice for pine, spruce, and fir applies to nurseries with little or no previous disease-control experience. It must be borne in mind that all of the chemicals and chemical compounds used, are more or less poisonous. For using chemicals, nurserymen are urged to acquaint themselves with the manufacturer's precautions.

Where Treatments Are Advised:

On soils where pH value is 5.3 or below, no treatment should be required except for places where experience has shown that damping-off may cause losses. On soils of any pH value on which as many as 3 seasons' experience has not shown damping-off losses to be above 10 or

15 percent, chemical treatments for disease control would not be practicable unless the stock is of special value or the treatment would also be of value as a weed-control measure. At some nurseries the weed control effect of the damping-off treatment more than pays the cost of treatment. On soils where the pH value is above 5.3 and there is no past experience to serve as a guide, treatment of part of the seedbeds is advised; the area to be treated will depend on the degree of apparent hazard. If the pH value is as high as 6.0, it would be reasonable to treat as much as one-fourth of the area planted with species susceptible to damping-off. If the pH value is 7.0 or above, it might be advisable to treat one-half of the area the first year.

What Species Should be Treated:

Among the important species that have proved to be highly susceptible are red pine, and, somewhat less in need of protection, jack, longleaf, shortleaf, and ponderosa pines, Douglas-fir and the spruces. Conversely northern white pine, nut pines, and the southern pines other than longleaf and shortleaf pines have in general not needed seedbed treatment for damping-off control. Ordinarily none of the cedars, with the possible exception of species of *Cedrus*, needs seedbed treatment to control damping-off.

Different species or strains of conifers may be expected to differ in their reaction to chemical treatments. There can be differences in the effect of the treatment either directly on the seed, on the seedlings, or on the amount of disease. In some localities these differences in reaction may be large enough to justify special precautions for certain species or strains of conifers. In general, seedbeds sown with seed native to alkaline or less acid sites, such as certain strains of ponderosa and Austrian pines, can be expected to have less need for acidifying treatments than seedbeds sown to species native to acid soils.

When to Treat:

Formaldehyde must be applied before sowing; application after seed is sown would kill a large part of the sown seed. On sandy soils seed should not be sown until 6 days after treatment in warm weather or 10 days after treatment if the weather is unusually cold. On heavier soils or those containing plenty of humus, 4 days in warm weather and 8 in cold weather should be sufficient. A single day is sufficient in some cases. Formaldehyde cannot be safely used on pines after emergence. Most tests for determining when to sow seed following formaldehyde treatment are either cumbersome or not thoroughly reliable; information regarding their use may be obtained by writing to the Division of Forest Pathology.

Treatments with acetic acid and chloropicrin are subject to time limitations much like those for formaldehyde.

Treatments of the surface soil with sulfuric acid, phosphoric acid, aluminum sulfate, or ferrous sulfate for controlling pre-emergence and ordinary damping-off losses are applied immediately following seeding. If the seeding is done in the very late fall so that there is no fall germination, treatments may be delayed until spring when they should be applied before the seed coats start to crack. Post-emergence treatments for controlling root-rot losses may be applied in the same amounts per square foot of seedbed area as the pre-emergence treatments, but at least 1 pint of water per square foot should be used in diluting them, or they should be followed with a

watering. Such treatments can be used with a fair degree of safety on most soils about 3 weeks after emergence, at which time the treatments are frequently of most value in the control of root rot. At nurseries where both ordinary damping-off and root rot are serious problems, it may pay to supplement pre-emergence treatments with similar post-emergence treatments at about the time the stem tissues begin to harden. For post-emergence treatments the sulfates are preferred to sulfuric acid; a blackening of the stems following application of ferrous sulfate does not necessarily indicate injury.

Deep acidification with acids or sulfates can be done at any convenient time before sowing. Where sulfur is used, it should be applied one season prior to the sowing of conifers as otherwise it may cause injury to the roots of the seedlings.

Surface Firing:

Surface firing, or burning of brush or other combustible material over seedbeds, just prior to seeding may give damping-off control, but the costs and the danger of ultimately making the soil too alkaline by the addition of the ashes prevent the recommendation of this method.

Chemical Disinfectants:

Formaldehyde is the safest material for use in controlling damping-off on any area where there has not been previous treatment experience. Generally it has been found to be fairly effective but relatively expensive in reducing damping-off. At nurseries attempting treatments for the first time, formaldehyde should be used on the greater part of the area designated for treatment. One-fourth fluid ounce of the strongest commercial formaldehyde should be applied per square foot of seedbed area. Formaldehyde should not be used after the seed has been sown. Further information on the use of formaldehyde is given under "When to treat" and "Technique in Applying Soil Treatments."

Acetic acid is about as effective as formaldehyde in controlling damping-off. It should be applied 5 or 6 days before seeding; one-half fluid ounce per square foot of seedbed area will give effective control on most soils.

Chloropicrin, usually more expensive than either formaldehyde or acetic acid and less extensively tried in nurseries, nevertheless is worth trial at places where effective control is not secured by using either of the other chemicals. Rates and methods of application prescribed by the manufacturer should be followed.

Surface-acidifying Treatments:

Surface treatment with sulfuric-acid solutions has long been used by some of the older nurseries. More recently both aluminum sulfate and ferrous sulfate have been employed as damping-off control measures. These two sulfates also increase acidity. Both sulfuric acid and the sulfates are applied just after seed sowing; they are cheaper and easier to use than formaldehyde, and on soils having a pH value of more than 5.0 they are on the whole more effective. The great difficulty with them is that the amount of chemical that should be used varies decidedly with the soil. The amounts of aluminum sulfate or ferrous sulfate that should be tested on soils with which there has been no previous experience are indicated in table 3.

TABLE 3.—*Amounts (avoirdupois) of aluminum sulfate or ferrous sulfate that should be tested on soils of varying pH*

Initial pH	Sandy soil		Heavy soil	
	Per square foot	Per 1,000 square feet	Per square foot	Per 1,000 square feet
	Ounces	*Pounds*	*Ounces*	*Pounds*
5.0	0	0	1/4	15.6
5.5	1/4	15.6	3/8	23.4
6.0	3/8	23.4	1/2	31.2
6.5	1/2	31.2	3/4	46.9
7.0	3/4	46.9	1	62.5
7.5	1	62.5	1 1/4	78.1
8.0	1 1/4	78.1	1 1/2	93.7

Where for any reason sulfuric acid is locally preferred to ferrous sulfate or aluminum sulfate, the number of fluid ounces recommended is one-fourth the number of avoirdupois ounces indicated in the tabulation. Where there has been no previous experience, it is desirable to make a preliminary test of the amount of acid material that is indicated in the table, by actually trying it on a few square feet of soil and determining the pH value 3 days later. If the top one-half inch of soil at this time has a pH value below 4.0, the treatment is heavier than it would be safe to employ on any considerable area. If the top one-half inch has a pH value above 5.0 three days after treatment, the treatment is not heavy enough.

From the standpoint of weed killing the sulfuric acid is probably the best of the materials advised for damping-off control, as the benefits obtained from weed control frequently offset the entire cost of the treatment. The sulfates are somewhat less effective against weeds, and formaldehyde is least effective. Zinc salts, efficient in weed control, also are effective in damping-off control, but they often prevent normal root growth of conifers. Copper sulfate gives fair control of both damping-off and weeds but is apt to injure conifer seedlings, especially if it is used on acid or even neutral soil.

Aluminum sulfate should not be confused with alum, which ordinarily means potassium aluminum sulfate. The technical granular grade of aluminum sulfate with the chemical formula $Al_2(SO_4)_3:18H_2O$ is the product which should be used. It can be obtained in bulk in most parts of the country. Experimental tests with aluminum sulfate from 8 different sources at one nursery and from 11 different sources at another indicated that there is no apparent association between source of the sulfate and effectiveness in reducing the amount of damping-off.

Hydrochloric acid, which has been used at a few nurseries, is more expensive than sulfuric acid or the sulfates and has no obvious compensating advantage. The volume required is about three times as much as of sulfuric acid.

Commercial phosphoric acid has given disease-control results of some promise. The volume required is about 2/1/2 times as much as of sulfuric acid; thus the number of fluid ounces used is about two-thirds of the number of avoirdupois ounces of sulfate that would be needed. It appears to be safer than sulfuric acid, and despite greater

cost it may hold an advantage over other acidic damping-off control treatments at nurseries where phosphorus is needed as a fertilizer.

On some neutral or alkaline soils, acidic treatments improve the growth of some species of conifers while formaldehyde has been observed to cause large growth increase on some acid soils. However, acid accentuates the natural leaching of soils, thus probably hastening impoverishment of those already acid. Aluminum and ferrous sulfates also accentuate the natural leaching, but probably not so much as a corresponding amount of sulfuric acid. Phosphoric acid also should result in less severe soil leaching than sulfuric acid. Objectionable caking of the surface soil has been reported in some nurseries following surface treatments with aluminum sulfate and sulfuric acid. Iron or aluminum compounds may be objectionable on some soils because of decreasing the availability of phosphorus. Repeated treatments with aluminum sulfate alone might result in harm from an excess of soluble aluminum, a condition that would be less likely if phosphoric acid or phosphates were used in mixture with it or in subsequent treatments. Except in soils already quite acid the likelihood of perceptible impoverishment by the small amounts of material added is believed to be slight. However, the unknown ultimate effect of repeated acidic treatment on the texture and fertility of the soil should be considered, especially if the land may later be used for nonconiferous crops. This is one of the reasons for advising against treatment in places where the disease hazard is slight.

Special Treatments for Longleaf Pine:

Damping-off of longleaf pine, generally grown on fairly acid soils, requires specific attention. The best safeguards against damping-off losses in this species are shallow seeding, the use of a well-decayed sawdust mulch on the seedbeds in place of drilling the seed or covering it with soil or sand (in broadcast-sown seedbeds, burlap or brush is needed on top of the sawdust to prevent it from blowing away), and the avoidance of any cultural practices that mound the soil around the crowns of the seedlings. Regulating the overhead sprinkling system so that the water falls on the soil as a fine spray rather than in large drops should also prove of value on fine sandy soils. Removal of sand and dirt from the crowns of the seedlings is most practicable at small nurseries. Control by this practice has been satisfactorily demonstrated on small-scale experimental plots. The frequency of removing the sand or dirt from the seedlings depends of course upon its rate of accumulation. Losses from this disease sometimes have been less in fall-seeded than in spring-seeded longleaf-pine seedbeds. If losses occur in the seedbeds, the disease may be brought under control in one of several ways. The best control results, through the use of chemical agents, have been secured from Semesan that is applied at the time the loss first begins to make its appearance. Effective damping-off control at a low cost has been secured by sprinkling Semesan at the rate of one-tenth ounce in 1 pint of water per square foot onto the groups of seedlings obviously attacked and for a distance of 1 to 1½ feet beyond the area of apparent killing. This treatment should be applied either late in the afternoon or on cloudy days, as it is known to have injured seedlings when applied at noon on cloudless days. For seedbeds in which the losses are distributed over the entire seedbed rather than occurring in spots,

the cost of treatment probably would be prohibitive. Rather heavy applications of ferrous sulfate, three-eighths ounce dissolved in 1 pint of water per square foot of seedbed area, applied at time of sowing, have given some promise of conttrolling this disease.

Deep Acidification:

As most naturally acid soils are relatively free from damping-off, it might be supposed that artificial deep acidification to a pH value of 5 would serve as a semipermanent safeguard against damping-off and root-rot epidemics. Tests at a number of nurseries have in general been disappointing, the degree of disease and weed control being much less than with the surface treatments already described. However, if nurseries are already established or have to be established where the soil is so alkaline that the pH value is near 8, surface treatments are not adequate and deep acidification may be necessary. It is believed safe to add enough acid to such soils to bring the pH value down to 5.5; but it would be advisable only for areas that are likely to be kept in conifer production for some years and then only if the amount of material required does not prove to be too expensive. Acid peat or humus, sulfuric acid, ferrous or aluminum sulfate, or probably better, a mixture of these, may be used, or in some cases sulfur. At the Federal or State nurseries that have been supplied by the Division of Forest Pathology with buffer or acid-requirement graphs the amount of sulfuric acid, aluminum sulfate, or ferrous sulfate needed can be read directly from the graphs. For others, tests will have to be made at the nursery by mixing different amounts into a number of small plots and determining the pH value of the soil. On the acid- or sulfate-treated plots 3 days probably will be sufficient for the soil to reach an approximate equilibrium, but a month or more may be necessary with sulfur, acid peat, or humus. After soil is once thoroughly acidified, the process will not need to be repeated for some years but for really efficient control it may still be necessary to use acidic or formaldehyde surface treatments each year that pine seedlings are grown.

Sulfur, the cheapest acidifying agent, long used on potato production soils, not only requires some months for oxidation before it becomes fully effective as an acidifier, but in nursery tests where it was applied shortly before sowing it was found to injure pine roots, by intermediate products formed before oxidation is complete. There is no indication that the effectiveness of the sulfur treatment for the control of damping-off and root rot is dependent upon the kind of sulfur used. Sulfur can be safely used only where it is practicable to let the soil stand without tree seedlings for one summer season after treatments; under other conditions sulfuric acid or aluminum or ferrous sulfate, or some mixture of these, should be used in any acidification practices. If sulfur is used, it should be at the rate of 3 ounces (avdp.) for every 5 ounces (fluid) or sulfuric acid that previous tests have shown were required to obtain the desired pH value.

Technique in Applying Soil Treatments:

Commercial formaldehyde solution (about 40 percent strength) is regularly applied in water. Application in absorbent dusts does not appear to have enough advantage to warrant the complication. One pint of water per square foot is ordinarily used to dilute the formalde-

hyde; on wet soil a smaller amount of water is sufficient. The practices of covering or stirring the beds after formaldehyde application, sometimes recommended, do not appear to materially increase the effectiveness of the treatment, and in some instances the stirring of the soil seems to have reduced the beneficial effects.

Aluminum sulfate or ferrous sulfate can be applied dry by premixing in several times its volume of soil and later washing it in by watering; *but the powder, particularly aluminum sulfate, irritates the eyes and respiratory tract and usually should be dissolved before applying. Sulfuric acid should be poured into water; water should never be poured into the acid.* The amount of water used in applying the acids and sulfates should ordinarily be one-half pint per square foot if the soil is wet, and 1 pint if it is dry. For one-eighth fluid ounce of sulfuric acid per square foot this gives a volumetric concentration from $\frac{4}{5}$ to $1\frac{1}{2}$ percent, not departing greatly from the 1- to 2-percent solutions advocated by some. The concentrations of the chemicals in the surface soil after treatment depend partly on the amount of water already in the soil before the treatment. The concentration of the solution as applied is believed to be less important than the amount of the chemical itself per square foot. Even smaller amounts of water may be sufficient if the beds are watered promptly after treatment. Where treatments are applied to emerged seedlings, a minimum of 1 pint per square foot is advised. The seedlings should be sprinkled promptly after treatment in order to wash the adhering dilute acid solution from the tops.

Hand sprinkling cans with the holes in the rose somewhat enlarged can be used with fair speed in applying solutions, but in large-scale operations barrel sprinklers (fig. 11) mounted on wheels are cheaper to operate and, if properly used, give more even distribution of solutions. Lead linings and pipes, or paraffin coatings for hand sprinklers are needed if sulfuric acid is to be applied. Barrel sprinklers are pulled over the beds twice in opposite directions in order to give both ends of the bed the same amount of solution. Application of materials other than acids theoretically could be made through the overhead sprinkler lines at a minimum cost, but the uniformity of mixing and distribution would have to be studied before this method could be safely used, and it would require the treatment of unseeded as well as seeded parts of sections, so its advisability is doubtful. For deep treatments, sulfur is mixed with soil, and other materials may be dissolved in water, applied to the soil surface and thoroughly worked in to a depth of 5–6 inches with the most convenient implements. For most acid materials pH determinations of the soil at different depths will enable the nurseryman to judge when he has secured a sufficiently uniform mixture.

Sulfuric acid requires special equipment to apply, and there is always danger of injury to clothes or to the operator himself. Wool materials are more resistant than cotton fabrics to injury from either the acid or sulfate treatments. Ferrous sulfate under some conditions might cause rust stain in the garments. If the clothing is properly washed within a short time after being in contact with either the ferrous or the aluminum sulfate solutions, little if any ill effects need be anticipated. If acid containers are opened carelessly or if water is poured into acid with resultant spattering, acid may be thrown into the eyes and cause injury.

Watering Treated Beds:

Formaldehyde-treated beds should be heavily watered just after sowing; thereafter they need no more watering than do untreated beds. Seedbeds treated with acid or sulfate should be kept especially moist until all seedlings have emerged. An amount of water that is quite sufficient for germination may yet be insufficient to prevent acid or sulfate injury to sprouting seed. If a sufficient water supply will

FIGURE 11.—Control of damping-off by applying acid solutions with a barrel sprinkler. (U. S. Forest Service photograph.)

not be available during the germinating period, large-scale use of acids or sulfates is not safe. A rainfall of 0.2 inch is equivalent to 1 pint of water per square foot.

Examination for Chemical Injury:

The more common type of injury by the acids and acidifying sulfates is killing or stunting the root tips just after the seeds sprout. To determine this, roots should be examined from a number of representative points *at the time when approximately one-half of the seedlings have dropped their seed coats.* If the examination is delayed until after the seed coats have all dropped, there may be so much decay of injured roots that it will not be possible to distinguish injured seedlings from

those that are damped-off. The most heavily treated seedbeds, spots in which the stand is thin, or seedbeds which have received less water are the ones to examine first. Seedlings with a bluish color above ground are most likely to show root injury. In the treated beds at this stage a certain amount of shortening or twisting of the roots does not necessarily indicate any real damage. If, however, the radicles of some of the seedlings have ceased to elongate before reaching a length of one-fourth inch, and have a brownish blunt tip in place of the white tapering tips of the roots of the same age in the untreated seedbeds, the seedlings are likely to die before they are able to put out new root tips. Figure 12 shows seedlings with different degrees of injury.

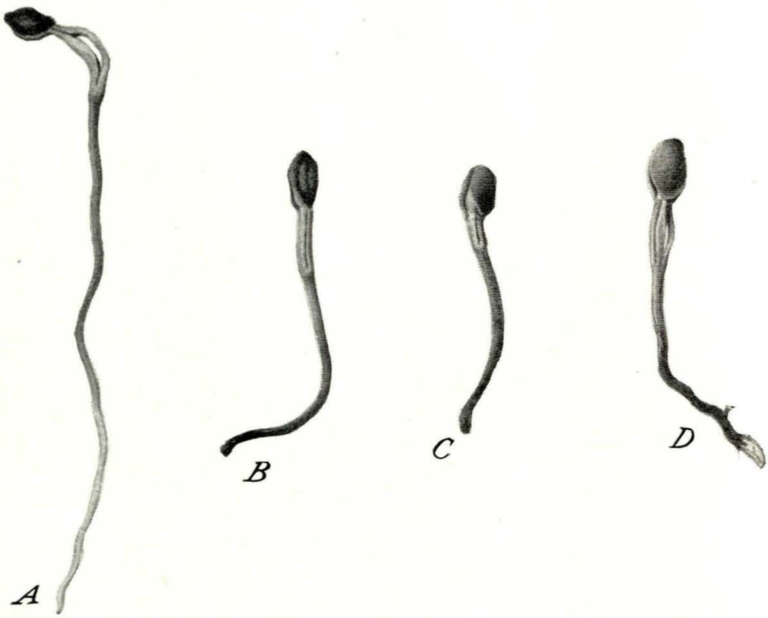

FIGURE 12.—Healthy and acid-injured pine radicles. *A*, Jack pine, healthy seedling. × 2. *B*, Jack pine, acid-injured. × 2. Probably not capable of recovery. The root growth was stopped before the seedling came up. The entire development of the stem and leaves above ground took place after the cessation of root growth. *C*, Corsican pine, acid-injured. × 2. Injured when so little root had developed that there was no possibility of a resumption of growth. Illustration made 10 days after the killing concentration occurred. *D*, Corsican pine, acid-injured. × 1½. Recovering by terminal resumption of root growth, as shown by the white root tip. (Drawn by Maybell S. Hartley.)

If some severely injured seedlings are found, enough seedlings should be examined to indicate how general the condition is, and the seedbeds should be kept especially wet for the next week to 10 days to allow such seedlings to get water through their short roots until they have a chance to put out new tips. Formaldehyde does not ordinarily cause injury of this type. In seedbeds treated with formaldehyde, injury is chiefly limited to the seed, and shows itself in the form of reduced emergence. In sulfate- or acid-treated beds there may be some seed killing. Acetic acid is such a weak acid that its effect is like formaldehyde and not like the acidifying materials.

Chemical injury from excessive treatments of conifer seed with such mercury dusts as Ceresan and Semesan is generally characterized by short root tips. These root tips may or may not be malformed. Frequently the stand is thin, growth subsequent to emergence is slow, and a number of the seedlings are chlorotic though the last symptom is not always present.

Treatments for Top Damping-off:

Normal strength Semesan and 4-4-50 Bordeaux have proved to be the most promising of the spray materials yet tested. These two sprays reduced seedling losses when applied at the rate of 1 gallon per 100 square feet of seedbed area. The treatment probably should be repeated one or more times at about 10-day intervals. Free air movement and avoidance of overdense stands are material aids in avoiding top damping-off. These treatments and preventive measures are also effective in controlling tip infection losses of older nursery stock.

Determining the Results of Treatments:

Occasional seedbeds or parts of seedbeds should be left untreated for comparison. It is also a good thing to give an occasional seedbed a treatment only two-thirds as much as the standard, and another seedbed or a small plot a treatment one-half again as much as the standard. When emergence is practically complete and before any considerable number of dead seedlings have disappeared, notes should be made on the number of seedlings that have emerged. The extent of the losses, and the cause (damping-off, birds, grubs, heat, etc.) should be recorded; where reliable help is available, records of total number of dead seedlings on small sample areas are desirable. Fairly reliable information may be obtained by recording the total number of seedlings emerged and total living seedlings at the end of the season. Where damping-off is heavy, a comparison of the final stands on treated and untreated beds is the best measure of results. Where counts are to be made, strips running diagonally across a seedbed and located at random or by some mechanical system that would prevent the count strips occurring in rows or at uniform intervals within the seedbed are more efficient than strips of equal area that run straight across. Actual tests made at different nurseries indicate that in general 80 diagonal strips give as reliable an estimate of the stand as could be obtained from 100 strips of equal area running straight across the seedbeds. For sampling a single bed the advantage of the diagonal strips should be even greater.

At some nurseries the treatments will have incidental effects that will be worth noting, such as stimulated growth of tree seedlings or reduction in number of weeds.

Spraying

Spraying with fungicides should be regarded as a preventive rather than a remedial measure. The primary object in spraying is to have the exposed parts of the plant covered with the spray so as to prevent germination of the spores or infection by the fungus.

In nurseries in the United States, summer diseases of the following conifers have required spraying: Longleaf and slash pines in the Gulf States (fig. 8), Austrian and Corsican pines in Ohio, red pine

in New Hampshire and West Virginia, Douglas-fir in Montana, red-cedar east of Colorado, red spruce in West Virginia, and hemlock at the higher elevations in North Carolina. The broadleaf species most frequently requiring spraying to prevent disease have been cherry, ash, and plum. For preventing the spread of *Rhizoctonia* or other top damping-off fungi directly from tree to tree, which occurs in crowded seedbeds, spraying is an inadequate safeguard, and, unless accompanied by thinning or other provision for allowing air circulation, it may result in little benefit. Spraying is effective in preventing the germination of spores on the surface of a plant; it is much more difficult to inhibit the spread of mycelium from plant to plant in direct contact. For specific advice as to kinds and concentrations of spray material to use for these various diseases, the reader should refer to "Cedar Blight," "Cedar Rusts," "Pine Gall Rusts," "Needle Spots," "Other Needle and Stem Diseases," and "Spruce Tip Killing."

Bordeaux mixture is the most generally effective fungicide, but sulfur or lime-sulfur sprays are effective against some diseases.

Injury to conifers from summer Bordeaux spray is practically unknown. It would be most likely to occur during long-continued wet weather. There is some reason to fear injury from sulfur or lime-sulfur in very hot weather. Where seedlings may be expected to mold under prolonged snow cover or under mulch, spraying with lime-sulfur solution before snowfall or before mulching in the autumn is preferable to Bordeaux mixture, since on seedlings during months of continuous snow cover the Bordeaux can cause injury to Douglas-fir and probably other species.

Chlorosis of pines, due to chemical deficiencies of iron, can be remedied to a considerable extent by spraying with a 1-percent solution of ferrous sulfate (the crude form is sold commonly under the name of "copperas"); the spraying may have to be repeated at about 10-day intervals. No adhesive is required, but the addition of an adhesive may make the treatment more effective.

Spreaders or adhesives must be used if good results are to be obtained with fungicides on conifers; they are also beneficial on most broadleaf species. Where there is danger of possible injury to foliage, as with linseed oil as a spreader, with any spray on cherry, or with the stronger sprays on species on which there has not been previous spraying experience, it is desirable to spray a small test plot before spraying the main body of seedlings. Casein-soap or fish-oil-soap spreaders may be used at the rate of 2 pounds in 50 gallons of Bordeaux solution. Different lots of casein soap may differ considerably in efficiency. Raw linseed oil at the rate of 2 or 3 quarts per 50 gallons is probably a more effective spreader but has to be emulsified. This can be done with Bordeaux mixture by simply pumping the mixture through the spray nozzle back into the tank. If oil is used with other fungicides it may be necessary to first emulsify it with soap at the rate of a pound of soap (preferably fish-oil soap) and a gallon of oil agitated in 4 or 5 gallons of water; the cheaper crude cottonseed or corn oil can be used in the same way, and a quart in 50 gallons may be sufficient. Milk appears to have given good spreading in preliminary tests on red-cedar; 1 gallon of milk in 50 gallons of spray mixture is suggested. Santomerse S used at the rate of three-fourths to 1 pint in 100 gal-

ions of Bordeaux has been found to be an effective spreader on southern-pine seedlings. Gas engine or power take-off pumps are advisable where redcedar, longleaf pine, or other species locally susceptible to needle diseases are grown in quantity, since the desirable pressures of 150 or more pounds are not likely to be maintained with hand pumps. The nozzles of the sprayer should be adjusted so that the spray is delivered in the form of a mist or fog, for if applied with driving force it will beat or pound the seedlings into the soil.

MYCORRHIZAE

Mycorrhizae are not classified among the diseases but must be described because absence of them has been associated with what appears to be deficiency diseases. Mycorrhizae are short, absorbing roots

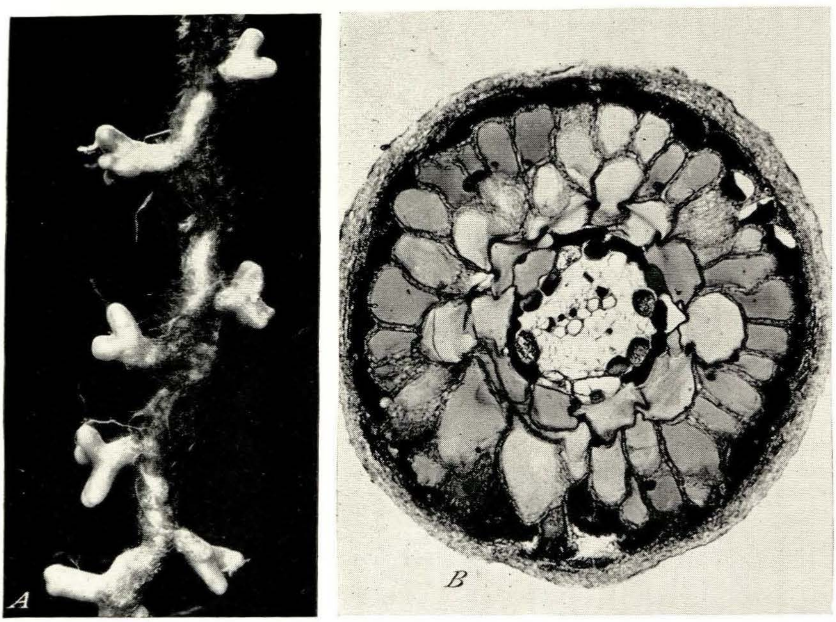

FIGURE 13.—Ectotrophic mycorrhizae. *A*, Enlarged bifurcately branched, mycorrhizal short roots. Note absence of root hairs. *B*, Photomicrographic cross section of mycorrhiza of loblolly pine, showing cloak of fungus threads around the short root and penetrating between the cortical cells. (Photographs by K. D. Doak.)

in which fungus threads or hyphae are intimately associated with the living tissues of the root. Conspicuous strands of fungi growing loosely over the roots are not sufficient basis for classifying them as mycorrhizae since many soil fungi may grow over root surfaces without producing the mycorrhizal structure. Ectotrophic mycorrhizae (fig. 13) are characterized by a compact scrface growth of hyphae regularly found on the important conifers. The so-called mantle or covering consists of several layers of hyphae; there is also found a layer of hyphae separating the outer living cells of the root cortex from each other. Root hairs are either absent from such infected

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short roots or crushed under the fungus mantle and rendered functionless, but the enlarged growth of this fungus-root structure and its connection with hyphae that spread extensively in the surrounding soil give it an absorbing surface, probably at least equal to that of a short root with root hairs. In soils with an adequate mineral nutrient supply, it probably makes little difference whether roots are mycorrhizal or uninfected. In actual field conditions, however, and in nurseries after the first year, uninfected short roots are so rare that there is no reason to consider them. Short roots that are not mycorrhizal are predominantly pseudomycorrhizal. These have no mantle and only a scanty internal infection with fungi apparently of a different group from the mushrooms or soil symenomycetes that are involved in the ectotrophic mycorrhizae. The pseudomycorrhizae, like the mycorrhizae, lack root hairs. They differ from mycorrhizae in that early maturity of cortex cells and deposition in them of materials such as tannins and resins which are impervious to water and nutrients appear to limit absorption to the slowly elongating light-colored root tip. When pine seedbeds are placed on soil that has not recently grown pines, these pseudomycorrhizae may be the dominant form during the first 2 or more years, and if the soil is not well supplied with mineral nutrients the seedlings may be badly dwarfed, or perhaps die. It seems possible that mycorrhizae may be beneficial by preventing the infection of the short roots by pseudomycorrhizal fungi. Mycorrhizae also seem to be less liable to attack by ordinary root-rot fungi. Especially from countries in which there are no native pines, complete growth failures of pine species have been reported on conifer-free sites unless soil or pine transplants were brought in from areas of good growth. At some of these sites it was only necessary to introduce single healthy and vigorously growing plants or small quantities of soil from around the roots of such plants at scattered points in the seedbeds, in order to obtain the necessary stimulant for good growth; various fertilizers at many of these places failed to stimulate satisfactory growth. There is little doubt that the beneficial results are derived from the introduction of some helpful organism, but the common assumption that the beneficial organisms are mycorrhizae-formers is not sufficiently supported by evidence. The frequent association between good growth and mycorrhizal development does not prove that either holds a causal relation to the other.

Striking results have been obtained in the United States by the use of 8 bushels of inoculating soil per 1,000 square feet. In areas that have not produced conifers within a 5-year period, it may be advisable to use the area for pine transplants before establishing seedbeds in it. In crop rotations at a nursery where transplants are grown and where past experience has shown seedling growth to be poor on new land, any herbaceous crop used in rotation should be grown before transplants rather than before seedlings. It should be emphasized, however, that at the majority of nurseries, including practically all of the long-established nurseries, unsatisfactory growth is associated with other factors more often than with the soil microbiology. Even at some nurseries where the pseudomycorrhizae predominate in the early life of the seedlings, the addition of fertilizers, particularly phosphates, appears to be a more efficient procedure for growth im-

provement than inoculations that might increase or hasten the production of ectotrophic mycorrhizae. In the Great Plains area sufficient tests on which conclusions may be based relative to the effect of mycorrhizae on the growth of conifer seedlings have not been made. Though inconclusive, there is some evidence that pine seedlings with mycorrhizae will give better survival and growth in plantations than seedlings on which they are lacking.

In the most commonly produced broadleaf species the mycorrhizae are endotrophic (fig. 14). Such mycorrhizae have no mantles and the

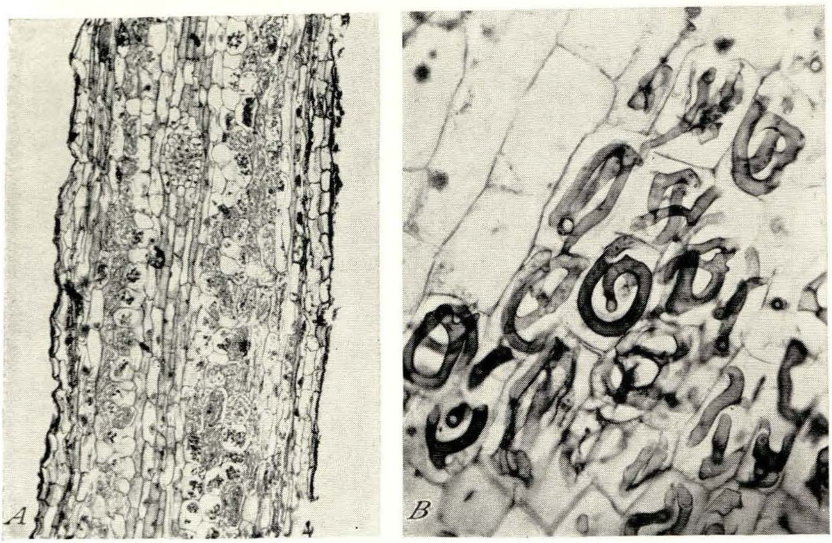

FIGURE 14.—Photomicrographs of endotrophic mycorrhizae of tulip poplar. *A*, Longitudinal section; note absence of cloak of fungal threads around root and between cortical cells. *B*, Threads of fungus inside the cells of the root. (Photographs by K. D. Doak.)

hyphae of the fungus is within the cells of the root. So far evidence indicates that inoculation of seedbeds in which broadleaf species are to be grown is unnecessary.

PREPARATION OF SPRAY MIXTURES AND CARE OF EQUIPMENT

Copper sulfate or blue vitriol goes into solution rather slowly, unless a powdered form is used; hence it is usually convenient to prepare a stock solution before the time the spray is to be mixed and used. Copper sulfate should be dissolved at the rate of 1 pound in 1 gallon of water and should be stored in glass or other noncorrosive containers. It can be dissolved more readily by placing the desired weight of chemical in a cloth bag which is suspended above the proper quantity of water, with the lower part of the bag just beneath the surface.

Either quicklime or hydrated lime may be used in the preparation of Bordeaux mixture. The hydrated lime is usually easier to obtain and handle and is therefore commonly used in the preparation of

this spray. A stock solution of lime may be prepared by stirring this material into water at the rate of 1 pound of quicklime or 1½ pounds of hydrated lime per gallon.

If difficulty is encountered in the preparation of the lime suspension, it should be remembered that the solubility of hydrated lime depends on the kind of water used. As a solvent for hydrated lime, hard water is less suitable than rain water, and it is often difficult to prepare a good milk of lime with hard water.

These stock solutions should not be combined directly if a good Bordeaux mixture is to be obtained. The spray is usually prepared by placing the required amount of the milk of lime into enough water to make up three-fourths of the desired volume of spray. The necessary amount of copper sulfate is poured from the thoroughly stirred stock solution into enough water (approximately one-fourth of the total desired volume) to make up the total volume of the spray. This solution is then poured slowly into the milk of lime, which must be stirred vigorously before the copper sulfate is added and while it is being added in order to prevent the settling of the lime.

It is sometimes convenient to weigh out the required amount of the hydrated lime and place it directly into enough water to make up three-fourths of the desired amount of spray. This makes it unnecessary to carry a stock solution of the lime into the field. Thorough agitation of the milk of lime is required in either method if a good Bordeaux is to be prepared.

A 4–4–50 Bordeaux mixture contains 4 pounds of copper sulfate and 4 pounds of quicklime, or 6 pounds of hydrated lime in 50 gallons of water. When stock solutions have been prepared as suggested, 4 gallons of each stock solution and 42 gallons of water will be required to make up 50 gallons of spray.

As it is frequently desirable to make up small quantities of spray, table 4 is presented to give the correct amounts of water and stock solutions needed to make up various quantities of 3–4–50 Bordeaux mixture.

TABLE 4.—*Correct amounts of water and stock solutions to make up various quantities of 3–4–50 Bordeaux mixture*

Desired volume of spray (gallons)	$CuSO_4$ solution	$Ca(OH)_2$ solution	Water
	Pints	*Pints*	*Gallons*
12.5	6	8	10.8
5	2.4	3.2	4.3
2	.96	1.28	1.7

Where power sprayers are being employed, it is advantageous to use either the powdered or "snow" form of copper sulfate and hydrated lime. Only fresh supplies of the hydrated lime should be used. To prepare an 8–8–100 Bordeaux mixture, pour about 25 gallons of water into the tank of the sprayer and start the agitator. Place in the strainer 8 pounds of powdered copper sulfate and wash into the tank with about 50 gallons of water. Add 8 pounds of hydrated lime made into a paste (mixture of lime and water). With the agitator still running, bring the mixture up to its full volume of 100 gallons. If a spreader is to be used, add it after the lime.

Bordeaux mixture is corrosive to metals and should be thoroughly washed from all mixing cans and sprayers after spraying is finished. Lead-free gasoline is very effective in removing Bordeaux-linseed oil emulsion from equipment. Special care should be taken to clean all small sprayer parts, such as valves and nozzles, which may be partly clogged with residue or dirt after the sprayer has been in use for some time. A fine-wire screen placed over the opening of the sprayer while the mixture is being poured will materially assist in keeping nozzle clogging by dirt and lime chunks at a minimum.

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